EB-2018-0165

Toronto-Hydro Electric System Limited

AMPCO Compendium

Panel 1

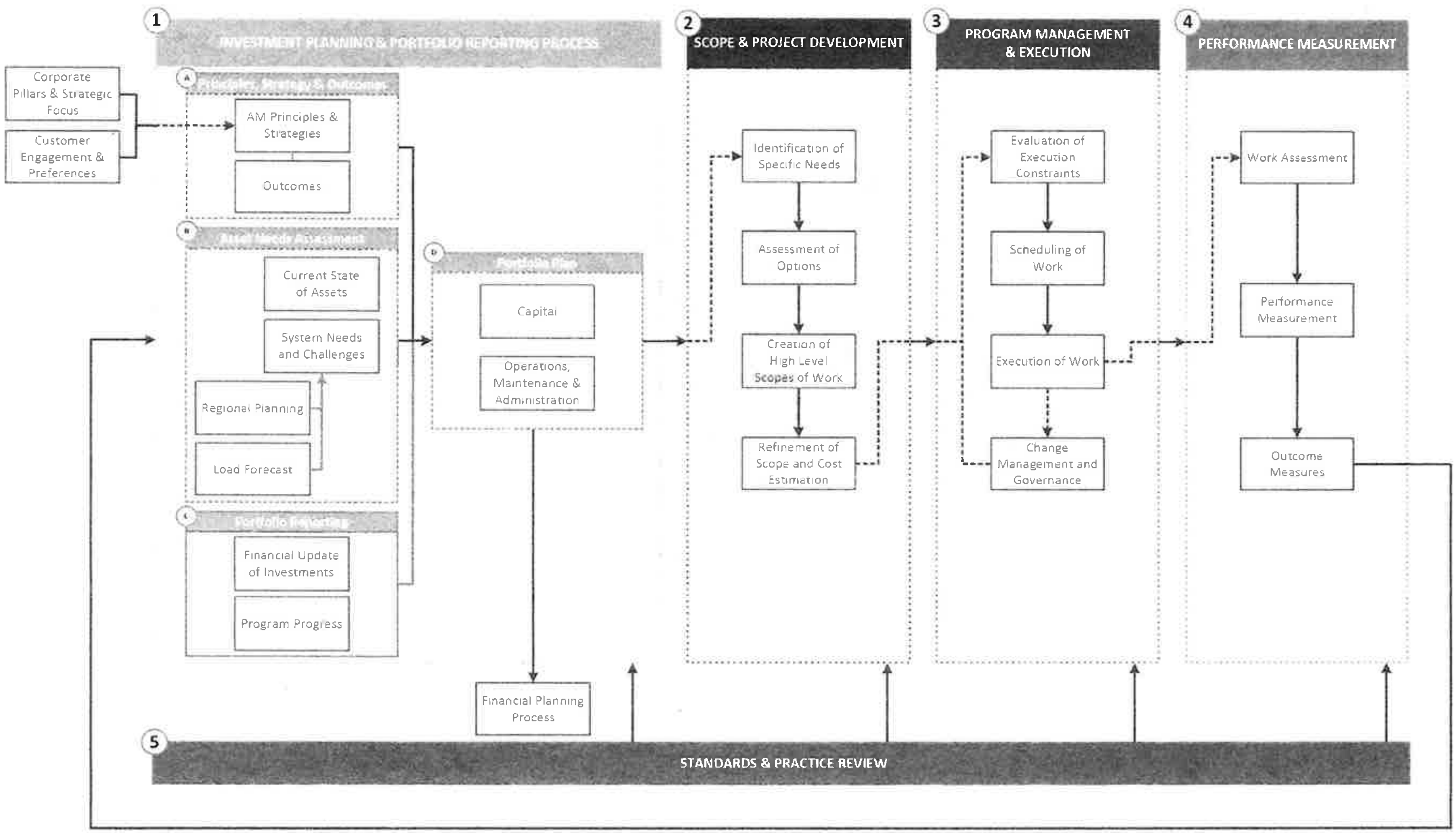

Figure 2: Asset Management Process Overview

The following sections outline each main component of the AM Process.

D1.2.1 Investment Planning and Portfolio Reporting ("IPPR") Process

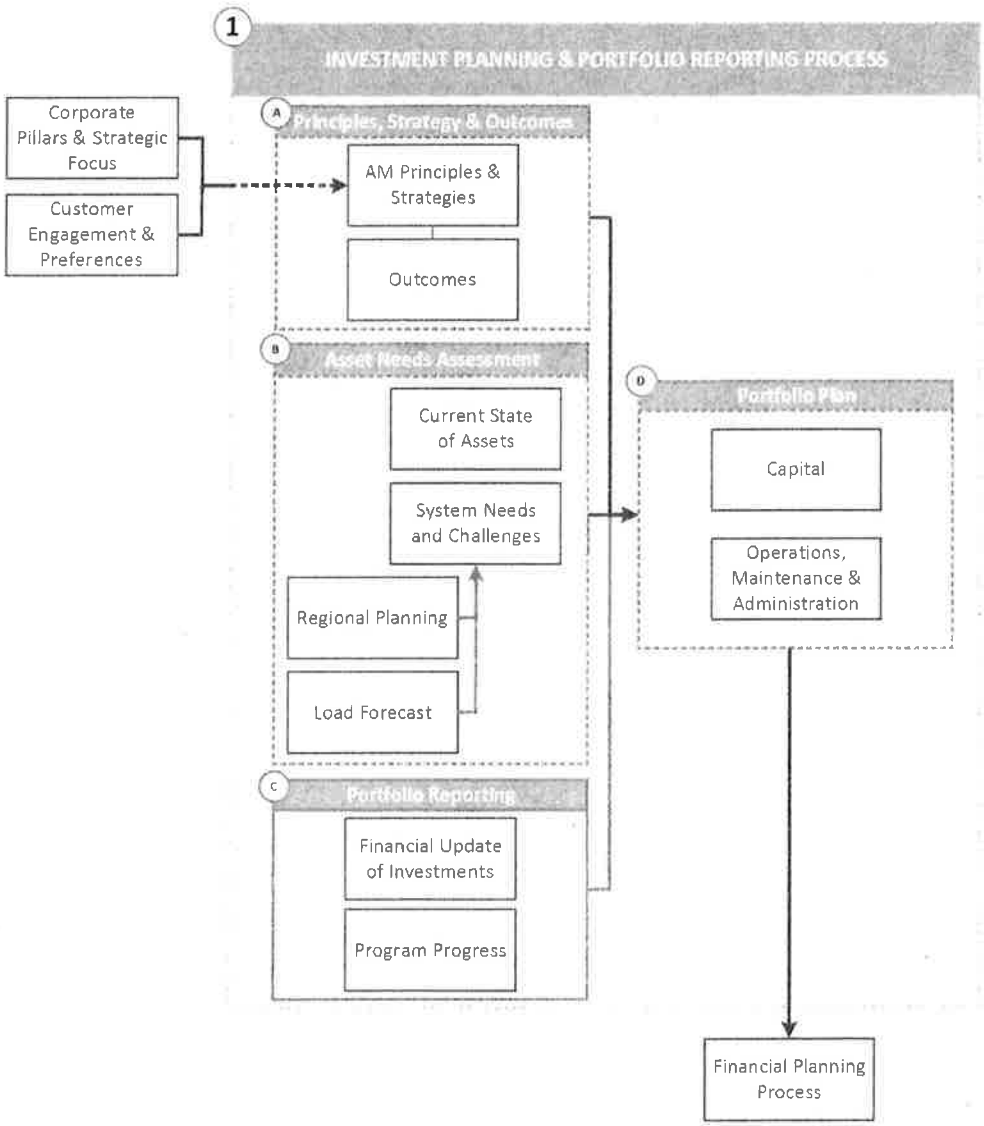

Figure 3: IPPR Process

The IPPR process is Toronto Hydro's system investment planning cycle, which includes both long-term and short-term planning horizons. It is composed of four sets of activities:

New Inspection Forms
Building off the experience gained with the first iteration of the ACA (2008) and the implementation of mobile inspections (2012), Toronto Hydro completed a full review and implementation of new inspection forms to capture in greater detail, and in a more effective and standardized manner, asset conditions for distribution and stations assets.

Investment Planning & Portfolio Reporting (IPPR)
Implemented a bundled and enhanced annual planning process for reviewing and updating investment strategies and plans. This process will continue to mature throughout the 2015-2019 DSP period as Toronto Hydro gains additional experience with the enhanced outcomes framework.

Development of an Outcomes Framework
Developed and implemented a customer-focused outcomes framework that aligns Toronto Hydro's business planning processes, including IPPR, with the utility's corporate strategic pillars, the OEB's RRF outcomes, and the outcomes that ultimately matter most to Toronto Hydro customers as expressed through customer engagement.

Reliability Centered Maintenance (RCM) Updates
Completed a full review and update of Reliability Centered Maintenance analyses.

Implementation of New Analytics
Implemented new analytics (i.e. data blending and visualization) tools and a data warehouse containing data relevant to asset management and investment planning decision-making from a variety of systems across the organization (e.g. ERP, GIS, CIS, OMS, metering).

ACA Methodology Transition
To improve the quality and rigour of the ACA, including the use of condition modelling over longer-term planning horizons, the utility began a transition away from a weighted average methodology to the Common Network Asset Indices Methodology (CNAIM) – a leading approach for deriving and projecting asset health developed and adopted in the United Kingdom by the regulator (i.e. OFGEM) and distributors.

CIC Study *(ongoing)*
A Toronto-specific customer interruption cost (CIC) study is underway to engage and better understand customer reliability experiences and to obtain data for the purposes of assessing specific investments through an economic lens that includes quantified customer impacts.

Enterprise Resource Planning (ERP) System *(ongoing)*
Implementation of a new Enterprise Resource Planning (ERP) system is underway, including new Enterprise Asset Management functionality.

Freeze/Thaw Resistance Product Trials *(ongoing)*
Trials for products that can be applied to underground assets to improve freeze-thaw resistance and reduce permeability to moisture are underway, with the potential to improve reliability and extend asset life in specific applications.

ISO 55000 Alignment Review *(proposed)*
Completion of an alignment review comparing Toronto Hydro's AM Process, tools, and approach to the international standard for Asset Management.

1 **Figure 7: Recent Enhancements of the AM Process (2015-2019)**

of spend to manage risk and in turn achieve the intended outcomes. Based on the driver of the work, investment programs are established as part of this step.

4) **Portfolio Reporting:** Once investment programs have been executed in the field through individual projects, the IPPR process includes a feedback loop where the project-specific execution status and project expenditures are reported to evaluate the projects proposed in upcoming years.

D3.4.1 Asset Management Strategies and Outcomes

As discussed in Section D1, Toronto Hydro's AM Process is guided by strategies and related outcome objectives that the utility sets in alignment with its corporate pillars and Customer Engagement results. Figure 4 in Section D1 provides a summary of the AM strategies and outcomes, and Section E2 provides an overview of how Toronto Hydro established its AM outcome objectives for the 2020-2024 DSP.

Toronto Hydro uses outcome measures in each outcome area to quantify the impact of investments towards each outcome. This framework is integral in enabling decision-making for asset management in both the long-term and short-term. Toronto Hydro's Custom Performance Measures for the 2020-2024 period are discussed in detail in Section C.

D3.4.2 Asset Needs Assessment

In order to create an optimized program, Toronto Hydro completes a needs assessment. In this regard, an important tool is the current state analysis ("CSA") which provides Toronto Hydro with an assessment of the major assets that are currently installed in the system.

Key parameters that are collected from and integrated into the CSA include:

- asset registry data (e.g. nomenclature, asset class/sub-class, installation type);
- asset quantity data;
- age and condition demographics data; and
- asset-class and system-wide replacement value based upon useful life criteria.

The CSA utilizes information from Toronto Hydro's various enterprise systems, including the Geographic Information System ("GIS") and Enterprise Resource Planning ("ERP") system to establish the core asset registry data and asset demographics. Through the development of the CSA, Toronto

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Hydro can quickly establish key information on major assets including condition, age, useful life, and replacement value.

There are two key outputs from the CSA process:

- **Asset demographic data:** Provides a yearly break down for the number of asset units installed along with their respective costs. As a key input for a data driven long-term planning process, this data set ultimately allows Toronto Hydro to establish the percentage of assets past useful life.
- **Condition demographic data:** Indicates demographics from a HI perspective for each asset class and sub-class, helping to flag higher risk assets within the system from a condition perspective.

This process establishes foundational data that is used in the long-term and short-term planning processes for distribution assets. Figure 7 illustrates the inputs, elements, and outputs associated with the CSA.

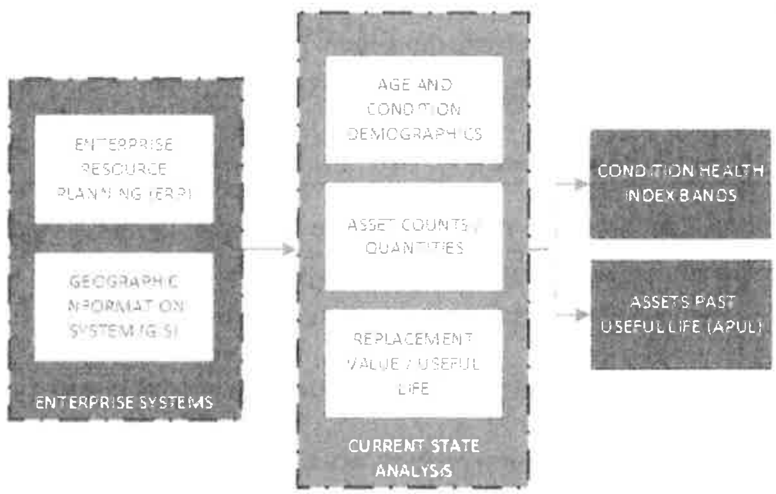

Figure 7: CSA Process

In addition to asset specific data, Toronto Hydro assesses emerging needs and challenges of the system by evaluating additional risk factors. For example, Toronto Hydro evaluates the available and forecasted capacity of the system to identify capacity related risks. As discussed in Section D1.2.1.2 as well as D3.3 above, this is done through load forecasting, load and generation connections forecasting, as well as the Regional Planning Process. These processes enable Toronto Hydro to

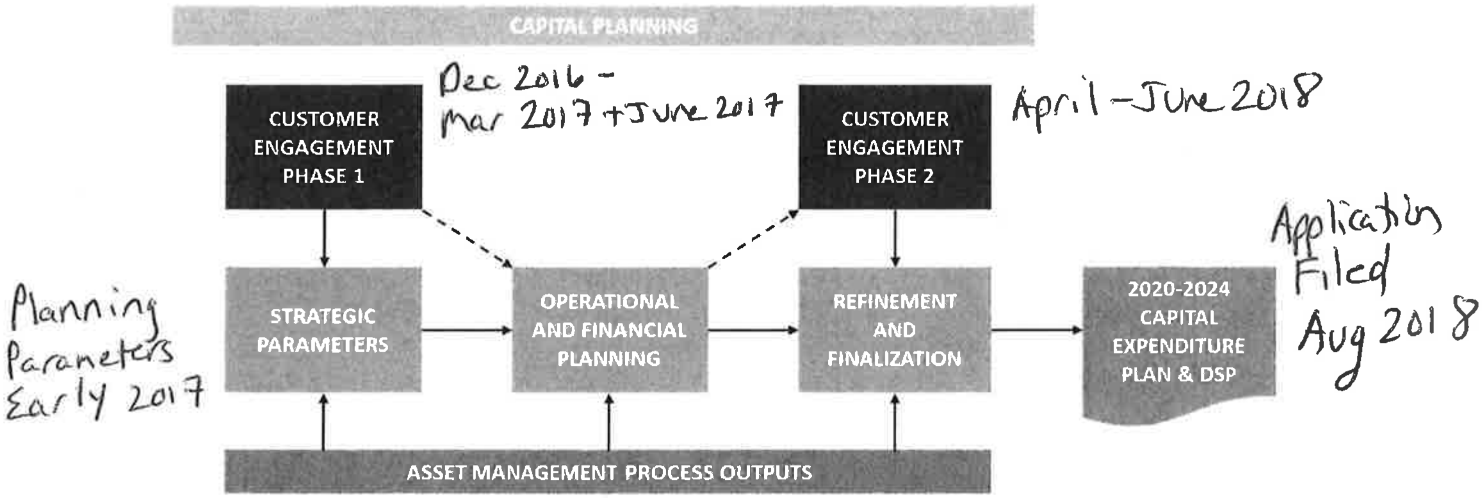

Figure 1: Capital Planning in Business Planning

The following sections provide an overview of how the elements of business planning came together to generate the capital plan that forms the basis of Toronto Hydro's 2020-2024 Distribution System Plan.

E2.1.1 Customer Engagement and Strategic Parameters

Toronto Hydro began business planning by engaging customers (i.e. Phase 1 of Customer Engagement) and using the feedback received to help set the initial strategic parameters for the business planning horizon. Feedback from customers was that price, reliability, and safety were their top three priorities. Overall, most customers preferred prices be kept as low as possible while maintaining average reliability performance and improving reliability for customers experiencing below-average service. [1]

With consideration for customers' priorities and preferences and other inputs (discussed below), Toronto Hydro set the following strategic parameters for the capital plan:

1) **Price Limit:** Toronto Hydro set an upper limit of 3.5 percent as a cap on the average annual increase to base distribution rates.[2]
2) **Capital Budget Limit:** Toronto Hydro set an upper limit of $562 million for the average annual capital plan budget, which corresponded with capping infrastructure and operations

[1] The results of Customer Engagement, Phase 1, are discussed in detail in Section E2.3.
[2] As calculated for the monthly bill of a Residential customer using 750 kWh.

TABLE 2: PROPOSED PERFORMANCE MEASURES FRAMEWORK

Customer-Oriented Performance	Cost Efficiency/ Effectiveness of Planning and Implementation	Asset/System Operation Performance
1. System Average Interruption Duration Index (SAIDI). 2. System Average Interruption Frequency Index (SAIFI). 3. Customer Average Interruption Duration Index (CAIDI). 4. Feeders Experiencing Sustained Interruptions (FESI). 5. Momentary Average Interruption Frequency Index (MAIFI).	1. Distribution System Plan Implementation Progress. 2. Planning Efficiency: Engineering, Design and Support Costs. 3. Supply Chain Efficiency: Materials Handling On-Cost. 4. Construction Efficiency: Internal vs. Contractor Cost Benchmarking. 5. Construction Efficiency: Standard Asset Assembly Labour Input.	1. Outages caused by defective equipment. 2. Stations capacity availability.

For a detailed discussion of these measures, their technical definitions, and the expected outcomes over the DSP forecast period, please refer to Section C of the DSP.

For each proposed measure, (with the exception of new measures) Toronto Hydro provides performance results along with the associated trend over the recent years, describes the methodology used to calculate the measure and its implementation, and outlines the ways in which the measure informs and/or otherwise interacts with the utility's DSP and the related processes. Where relevant, Toronto Hydro also describes the unique planning and implementation considerations that shape the measure's design and the utility's expectations as to its future performance levels.

5 Asset Management Process

Toronto Hydro's AM Process, which is explained in detail in Section D, can be broken down into five major components: (i) the planning process, (ii) the associated decision-support systems, (iii) the enterprise databases that support both the planning process and systems, the (iv) distribution system plan itself that is supplied by outputs from the planning process, and finally (v) a measurement and enhancement process that supports continuous improvement. Figure 12 depicts the AM process and its various elements and support systems.

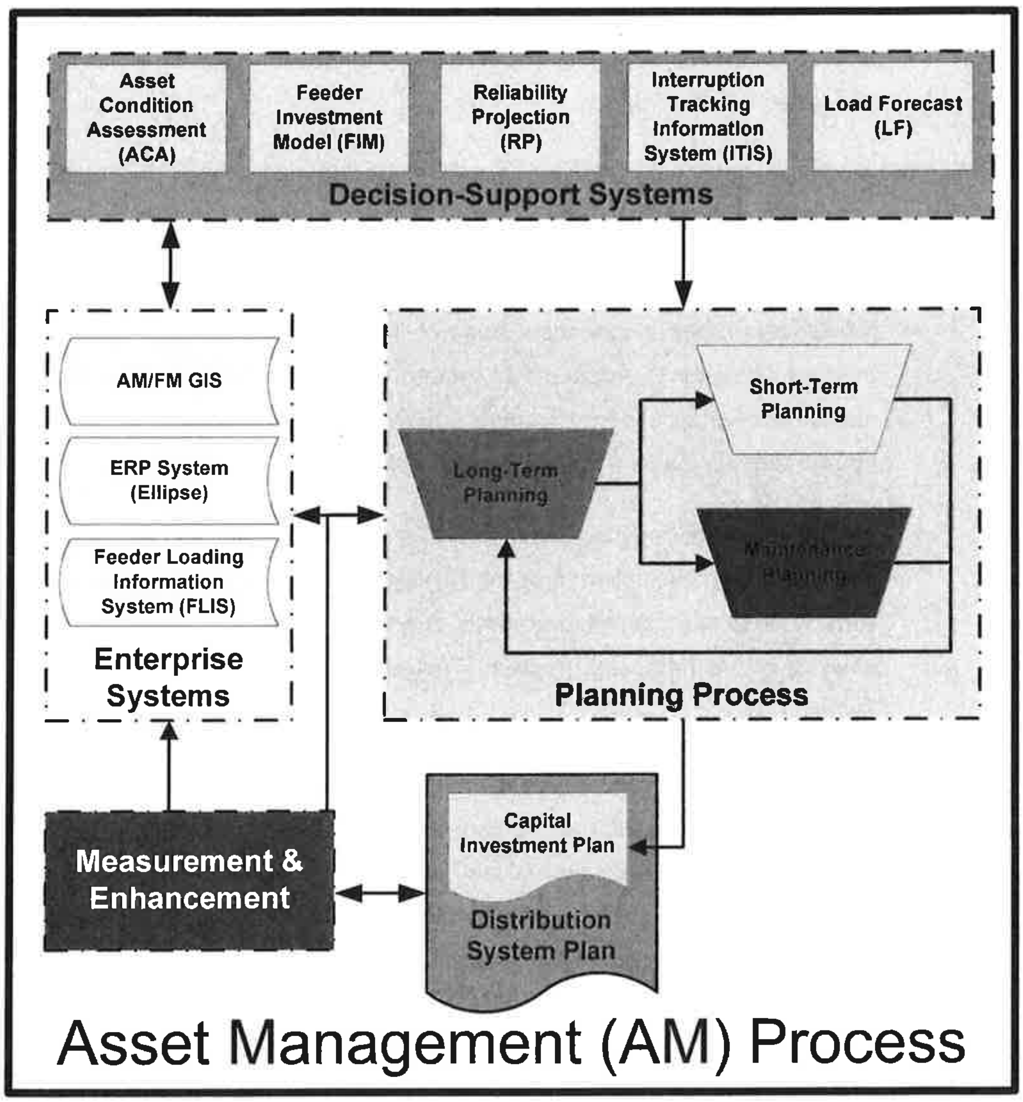

FIGURE 12: ASSET MANAGEMENT PLANNING PROCESS OVERVIEW

The planning process element of the AM process can be further subdivided into three stages:

(i) Long-term planning, discussed in detail in Section D1.2.1, results in the development of a capital investment approach and execution strategy along with corresponding investment programs that align to AM objectives.

(ii) Short-term planning, discussed in detail in Section D1.2.2, results in the production of discrete projects within each investment program.

(iii) Maintenance planning, discussed in detail in Section D1.2.3, focuses on extracting the maximum value out of Toronto Hydro's distribution system assets, through inspections, upkeep and repair activities. The outputs from the AM Planning Process as a whole are integrated into the DSP.

Toronto Hydro is continually monitoring and improving decision-support systems, enterprise systems and various inputs that support the AM planning process. Recent improvements include the following:

- Kinectrics, in their independent audit of Toronto Hydro's Asset Condition Assessment program (Chapter D, Appendix A), notes that Toronto Hydro has worked to improve its maintenance practices in a number of ways, including improved asset inspection forms and an expanded scope for transformer oil testing.
- Toronto Hydro introduced additional quantifiable benefits as an enhancement to the business case evaluation process. This allows for a broader set of benefits to be considered in the quantified analysis, thereby allowing for a more accurate and robust analysis of the proposed program. This enhancement is further discussed in detail in Section D3.
- Toronto Hydro has made efforts to improve data quality within its enterprise geographical information system (GIS) and enterprise resource planning (ERP) system respectively such that improved decision making can be performed at both the long-term and short-term planning levels. This includes development of data quality reporting processes, consolidation of data from the two systems, improvement of connectivity of information within systems, etc.
- Toronto Hydro has improved on various elements of the Asset Condition Assessment process. Key improvements include increased sample size of each asset category and improvements to the Business Intelligence Calculator

6 Customer Needs and Preferences

In accordance with the OEB's requirement to obtain information on customer preferences, Toronto Hydro has engaged with its customers specifically around the utility's DSP for 2015-

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RESPONSES TO CONSUMERS COUNCIL OF CANADA INTERROGATORIES

INTERROGATORY 9:

Reference(s): Exhibit 1B, Tab 1, Schedule 1

THESL has filed and Executive Summary and Business Plan Overview. Please file the actual 2020-2024 Business Plan approved by the THESL Board. Please provide a detailed description of the Business Planning process.

RESPONSE:

The Business Plan that underpins this Application and that was approved by the Board of Directors is filed at Appendix A to interrogatory 1A-CCC-1. As this was the final Business Plan leading to the eventual filing of Toronto Hydro's rate application, it included the penultimate forecasted capital expenditure plan for the full 2020-2024 period. As explained in the following description of business planning, the 2018-2020 Business Plan was a corporate deliverable within the business planning process that led to the final plan filed in this application.

<u>Toronto Hydro's Business Planning Process for the 2020-2024 Custom IR Application</u>

1. Beginning in late 2016, Toronto Hydro generated a high-level assessment of its operational needs, and undertook a first phase of customer engagement to receive feedback on customer needs and priorities. Please see Exhibit 1B, Tab 3, Schedule 1, for more details about Toronto Hydro's Phase 1 Customer Engagement.

2. The utility considered the results of this first phase of customer engagement alongside its legal obligations and business input to set its outcomes framework and high-level planning parameters in early 2017.

3. Next, Toronto Hydro proceeded with its operational planning and financial planning (i.e. budgeting) processes, building out and refining a business plan and strategic parameters for 2018-2024 that was completed in November 2017.

4. Toronto Hydro then took this plan back to customers in April and May of 2018, including a detailed breakdown of the plan. Please see Exhibit 1B, Tab 3, Schedule 1, for more details about Toronto Hydro's Phase 2 Customer Engagement.

5. Taking into account the feedback received in this second phase of Customer Engagement, the utility made additional refinements and adjustments to the plan, including changes to shift funding between certain programs to better reflect customer preferences. The supporting evidence was finalized and the application filed in August 2018. Please see Exhibit 2B, Section E2.3.2.3 and Toronto Hydro's response to interrogatory 2B-Staff-71, parts (a) and (b) for more details about changes Toronto Hydro made to its plan to reflect customer feedback received during Phase 2.

D3.2 Asset Lifecycle Risk Management Policies and Practices

Customer-focused outcome measures such as system reliability, safety incidents, connections efficiency, and oil spills are lagging indicators of system performance. These measures are essential to understanding the actual experience of customers, stakeholders, employees, and the general public in relation to the distribution system. However, certain lagging measures, by their nature, can be difficult to directly influence through actions taken in the near-term. This is especially true for measures that are influenced by asset failure. Toronto Hydro manages hundreds of thousands of distribution assets that are typically in service for decades. These asset can fail in a variety of ways at any point in their lifespan, and it is impossible to know with precision exactly when failure will occur. Therefore, in the daily effort to direct expenditures toward cost-effective interventions that will drive performance outcomes, Toronto Hydro must rely on risk – a leading indicator of performance – to make informed investment decisions.

As a large urban utility with a highly utilized system and a significant asset renewal need, risk assessment is essential to ensuring that system reliability and other outcomes can be maintained with a constrained expenditure plan.

This section outlines Toronto Hydro's lifecycle risk management methods and practices for its distribution assets, detailing the utility's risk assessment frameworks, including key considerations in risk evaluation, and typical risk mitigation approaches. Capacity related risk is discussed separately in Section D3.3.

D3.2.1 Overview of Risk Assessment Methods

Toronto Hydro's risk assessment framework consists of the following key elements:

- Probability of Failure;
- Consequence of Failure; and
- Risk Analysis.

Details of each key element follows.

D3.2.1.1 Probability of Failure

Probability (i.e. likelihood) of failure is an important consideration in determining whether asset intervention is necessary. This section focuses upon two key forms of analytics that are utilized to

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enable Probability of Failure evaluation: (i) Asset Condition Assessment ("ACA"); and (ii) predictive failure modelling.

1. Asset Condition Assessment (ACA)

As explained in Section D1 and in Appendix C to Section D, Toronto Hydro employs an ACA methodology to monitor the condition of various key asset classes within its system and produce a health index ("HI") score to support project planning. The ACA allows Toronto Hydro to use data collected data through inspections to produce a numerical representation of an asset's condition, taking into account key factors that affect its operation, degradation, and lifecycle. Toronto Hydro uses ACA to support tactical and strategic investment planning decisions. Planners use inspection data and individual HI scores – in combination with other information and professional judgement – to prioritize assets for tactical intervention in the short- to medium-term. This includes identifying priority deficiencies that require reactive or corrective action, and prioritizing assets for planned renewal projects in a given budget period. At a strategic level, Toronto Hydro uses ACA results to examine condition demographics and trends within major asset classes to support the development of longer-term investment plans within the annual Investment Planning & Portfolio Reporting ("IPPR") Process.

As part of the efforts to continually improve its asset management and decision-making framework, Toronto Hydro worked with EA Technology to develop new asset health models based upon the Common Network Asset Indices Methodology ("CNAIM"). CNAIM is the approach used by distribution network operators in the United Kingdom to report asset health as part of their regulatory reporting requirement. Toronto Hydro has used the outputs from this CNAIM-based model to support an advanced condition-based approach for planning and evaluating strategic capital investments. Toronto Hydro has provided additional details on the new ACA methodology in Appendix C to Section D of the DSP.

The approach used to develop the HI for each asset is illustrated in Figure 3.

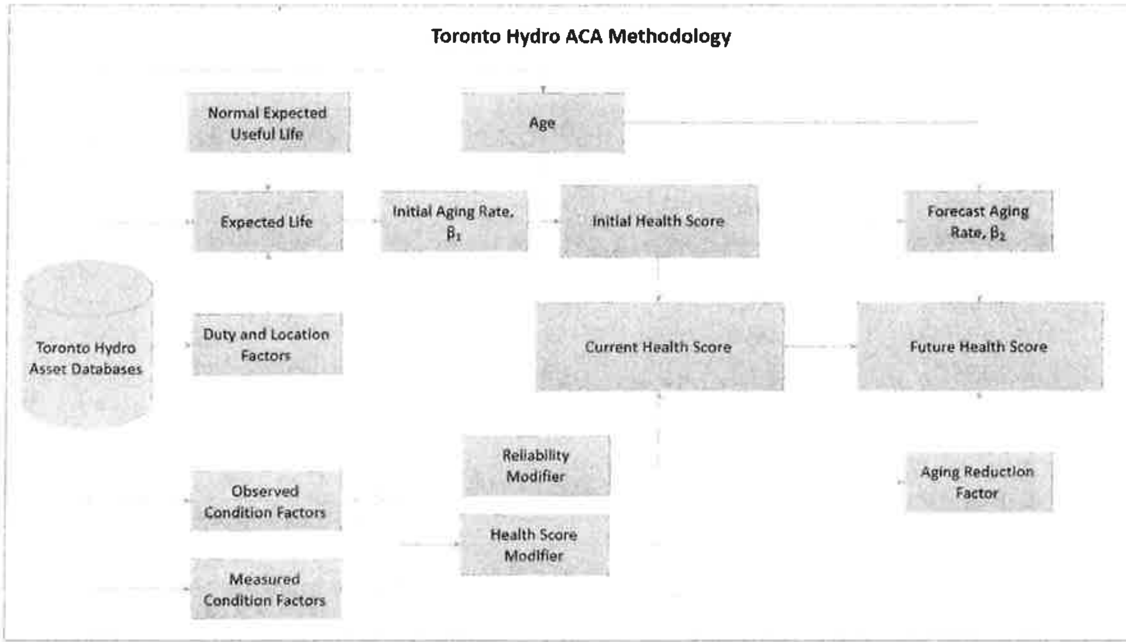

Figure 3: Asset Condition Assessment Process as Part of ACA

ACA results for a particular asset class are grouped into five HI bands that represent key stages of an asset's lifecycle, ranging from new or like new condition to the stage where asset degradation is significant enough to warrant urgent attention. Toronto Hydro uses asset HI demographics during the scope development phase of IPPR, as outlined in Section D1. It enables planners to assess the relative probability of failure of their assets in the short and mid-term timeframe based on the HI band. The bands are defined as per Table 7 below.

Table 7: Health Index bands and definitions

Band	Lower Limit of Health Score	Upper Limit of Health Score	Definition
HI1	≥ 0.5	< 4	New or good condition
HI2	≥ 4	< 5.5	Minor deterioration; in serviceable condition
HI3	≥ 5.5	< 6.5	Moderate deterioration; requires assessment and monitoring
HI4	≥ 6.5	< 8	Material deterioration; consider intervention
HI5	≥ 8	≤ 10	End of serviceable life; intervention required

Examples of asset classes with HI scores are shown in Table 8 below.

Table 8: Assets Evaluated in the ACA Program

Switches	Breakers	Vaults	Transformers	Other
• Overhead Gang-Operated • SCADA-Mate • Air-Insulated Padmount • SF_6-Insulated Padmount • SF_6-Insulated Submersible • Air-Insulated Submersible	• 4 kV Oil Circuit (MS) • KSO Oil Circuit (TS) • SF6 Circuit (TS) • Vacuum Circuit (MS & TS) • Air Magnetic Circuit (MS & TS) • Airblast Circuit (MS & TS)	• ATS • CLD • CRD • Network • Submersible Switch • URD	• Station Power • Network • Submersible • Vault • Padmount	• Wood Poles • Network Protectors • Cable Chambers

The ACA output is essential in two respects. First, the ACA produces a relative outlook of the population's condition for each individual asset class within the program. Second, the ACA program highlights trends in the condition of asset classes. These trends can highlight issues that are specific to particular asset classes or subtypes such as manufacturing defects, or design practices. For system planners, these insights along with the health band of an asset provide an indication of the probability of failure for an asset. Being aware of these issues and trends allows Toronto Hydro to balance capital investments against continuing maintenance. More generally, the ability to compare current and future health index results for an asset class can support decision-making when developing expenditure plan envelopes for longer-term investment programs. In its 2020-2024 DSP, Toronto Hydro has used this information to compare proposed investment levels against current and projected volumes of assets in the two worst health bands ("HI4") and ("HI5"). For more information, refer to Section E2.

For more information on Toronto Hydro's ACA approach, refer to Appendix C to Section D.

2. Predictive Failure Modelling

Predictive failure modelling represents the other essential component of the Probability of Failure analysis. It involves the derivation of hazard rate functions for each asset class – also referred to as the assets' probability of failure. In this case, an asset's age is used as an input into the hazard rate calculation in order to produce the conditional probability of an asset failing based on the remaining population that has survived up until that time. The results from these failure curves provide insights into the expected failure rates of assets, which is critical information for determining the investments required to manage assets over the medium term.

Toronto Hydro's hazard rate distribution functions were each calibrated to a useful life value. Toronto Hydro's useful life values are also used separately as part of the Assets Past Useful Life ("APUL") calculation, in order to assess the demographics of assets, especially those approaching or past their useful life. Toronto Hydro utilizes this information to ascertain the upcoming "asset walls" and investment requirements that will emerge over a long-term period, and better equip its planners to make informed investment decisions and develop effective plans based on the needs of the system.

The aggregate information extracted from predictive failure modelling combined with the APUL calculation can be used as an input in determining the levels of expenditures required for managing each asset type. The predictive failure modelling procedure is also used as part of the economic risk-based analysis and reliability projection procedures, which are further discussed in Section D3.2.1.3.

3. Historical Reliability Analysis

The last component of Toronto Hydro's probability of failure analysis involves the analysis of historical reliability data from the Interruption Tracking Information System ("ITIS"), in order to identify assets with a high frequency of failure.

ITIS is used to store historical outage information which Toronto Hydro uses as a key tool in developing capital spending. By continuously analyzing the reliability performance of its circuits and substation assets, Toronto Hydro is able to identify areas experiencing reliability issues, which may be caused by asset deterioration or legacy design related issues. Toronto Hydro utilizes the following ten major cause codes to classify historical outages within ITIS:

- Adverse Environment;
- Adverse Weather;
- Defective Equipment;
- Foreign Interference;
- Human Element;
- Lightning;
- Loss of Supply;
- Scheduled Outages;

- Tree Contacts; and
- Unknown.

From a Probability of Failure perspective, the data contained within ITIS can be used to identify those asset classes and sub-classes, as well as parts of the system that experience a high frequency of failure. As an example, ITIS data has been utilized as part of Toronto Hydro's planning procedures to identify feeders containing the most problematic direct-buried underground cables.

D3.2.1.2 Consequences of Failure

When determining the risk of asset failure, there are two components considered; the probability (explained in Section D3.2.1.1) as well as the consequences and impacts of failure, which go into to the specific failure modes and effects associated with those failure modes. These consequences are generally broken down into key categories that generally align with Toronto Hydro's outcomes framework (i.e. customer service, reliability, environment, safety, and financial impacts).

1. Customer and Reliability

Derivation of the customer or reliability impacts is undertaken through a number of tools and approaches, including:

- Customer engagement and consultation activities;
- Key account customer program and responses to customer calls and complaints;
- Reliability analysis identifying long-duration impacts; and
- Application of customer interruption costs.

Table 9 provides additional information related to each of the aforementioned tools and approaches.

Toronto Hydro Asset Condition Assessment Methodology

The primary benefits of CNAIM with respect to assessing asset health and probability of failure are expected to be as follows:

i. a robust scoring methodology that emphasizes deficiencies which directly impact equipment failure;
ii. fewer asset exclusions due to data availability;
iii. a stronger and more objective relationship between condition and probability of failure; and
iv. the ability to project future asset health scores, providing strategic insight into longer-term investment strategies using forecasted HI demographics.

To date, Toronto Hydro has implemented the aspects of CNAIM necessary to immediately achieve the benefits described in items (i), (ii) and (iv) above. For item (iii), Toronto Hydro is currently in the process of developing the formulas required to convert an HI score produced by CNAIM into a probability of failure.

Asset health and probability of failure are only one part of the CNAIM. The full methodology also addresses consequences of failure and asset criticality. This includes a common methodology for assigning monetized risk values to assets based on consequences of failure – a concept that is analogous to the avoided risk cost methodology in Toronto Hydro's existing Feeder Investment Model ("FIM").

Toronto Hydro's immediate objective in moving to CNAIM was to replace the functionality of the previous ACA, which did not include a consequence of failure or asset criticality component. Going forward, in addition to developing the incremental capability to convert an HI score to probability of failure, Toronto Hydro intends to explore the consequence of failure and criticality aspects of CNAIM. It will also examine opportunities to derive additional value from the existing FIM by connecting it with, or subsuming it within, the CNAIM approach to asset risk evaluation.

The following section describes Toronto Hydro's implementation of the CNAIM to date.

4. Toronto Hydro's Implementation of CNAIM

a. Formulation of ACA

1. Formulas

To date, Toronto Hydro's implementation of CNAIM has covered the derivation of current and future health calculations. Using the CNAIM framework, the current health of an asset is represented by a health score using a continuous scale between 0.5 and 10 (extended up to 15 for forecasting of future health), where 0.5 represents the condition expected of a new asset. A health score of 5.5 represents the point in

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an asset's life beyond which significant deterioration is likely to be observed. A health score of 10 represents an asset in a state unacceptable to Toronto Hydro.

The steps for deriving current and future health scores in the CNAIM framework include the following (Appendix A of this report provides additional details on the algorithm and each of the variables):

- Calculate an *Initial Health Score* based on the asset's age and expected life, taking into account its operational use (duty) and operating conditions.
- Determine the *Health Score Modifier* based on the known conditions of the asset, including information gathered from inspections the asset, diagnostic tests or measurements. The observed and measured condition inputs are used to determine the *Health Score Factor*, *Health Score Cap* and *Health Score Collar*.
- Determine *Reliability Modifier*, where applicable for the asset's subcategory to account for generic issues affecting asset health or reliability associated with a specific manufacturer or model type. The *Reliability Modifier* comprises a *Reliability Factor* and a *Reliability Collar*.
- Calculate the *Current Health Score* by multiplying the *Initial Health Score* by the *Health Score Factor* and the *Reliability Factor,* and applying the upper and lower thresholds defined by the *Health Score Cap* and *Health Score* and *Reliability Collars*.
- Generate the *Future Health Score* by inputting results into an equation that projects the asset's condition at a desired point in time.

For the purpose of reporting, the *Current* and *Future Health Scores* are mapped onto one of five HI Bands as follows, with *Current Health Score* represented on a continuous scale of 0.5 – 10 and *Future Health Score* represented on a continuous scale of 0.5 – 15:

Table 1: Health Index bands

HI Band	Lower Limit of Health Score	Upper Limit of Health Score	Definition
HI1	≥ 0.5	< 4	New or good condition
HI2	≥ 4	< 5.5	Minor deterioration; in serviceable condition
HI3	≥ 5.5	< 6.5	Moderate deterioration; requires assessment and monitoring
HI4	≥ 6.5	< 8	Material deterioration; consider intervention
HI5 (Current Health)	≥ 8	≤ 10	End of serviceable life; intervention required
HI5 (Future Health)	≥ 8	≤ 15	

2. Data Inputs

The data inputs required to calculate *Current* and *Future Health Scores* for an asset include age and condition and operation data. Condition data includes observations and test results recorded during routine maintenance and field inspections. Asset operation data relates to the use of the asset and varies based on the type of asset (e.g. percent utilization for transformers and number of operations for circuit breakers).

3. Differences between Ofgem and Toronto Hydro implementations of CNAIM

The Ofgem CNAIM model was built around 25 asset types that are common among U.K. utilities. In many cases, the manufacturing and functional characteristics of these assets differ from Toronto Hydro's assets. It was therefore necessary in Toronto Hydro's implementation of the CNAIM approach to adjust certain input factors and initial condition scores to accurately reflect the utility's system and operating realities. The two main areas included:

- adjustments to the caps and collars for each failure mode of an asset to reflect Toronto Hydro's experience with asset deficiencies and failures on its own system; and
- adjustments to duty values, i.e. the loading on an asset or the frequency with which it is used, to reflect the functionality and the way the asset is used in Toronto Hydro's operating context.

In making these necessary utility-specific adjustments, Toronto Hydro did not fundamentally alter or deviate from the core principles or methodology of CNAIM.

Toronto Hydro is exploring additional opportunities to align its implementation of CNAIM with the utility's operational reality. For example, environmental and climate conditions in the U.K. are different from those in Toronto. Toronto Hydro is currently working on developing appropriate location factors which will better define the environment in which the assets are functioning. In the interim, the location factor values are currently defaulted to a value of one, which is consistent with the CNAIM model for situations where the data is not available.

4. Third-party review of Toronto Hydro's CNAIM implementation

To ensure the appropriate implementation of the CNAIM model, including the validity of the aforementioned utility-specific adjustments, Toronto Hydro retained U.K. firm EA Technology to review its newly developed asset health models, recommend areas for improvement, and provide guidance and training to ensure organizational alignment with the asset management philosophy, principles and practices underpinning the CNAIM approach. Toronto Hydro selected EA Technology for this task as they are the foremost experts in the CNAIM model, having provided support for the development of the original methodology as well as the delivery and implementation of the common models to all U.K. distribution network operators.

The following section provides additional details on Toronto Hydro's approach to CNAIM implementation.

b. Approach to implementation

Through its Reliability Centred Maintenance ("RCM") framework, Toronto Hydro categorizes the failure modes and deficiencies for each asset type and documents maintenance strategies for mitigating deficiencies. The utility used RCM information to build the Health Score Modifiers – i.e. the observable and measurable condition variables that modify the health score of an asset – for each asset type modeled in the CNAIM. Unlike Toronto Hydro's legacy ACA methodology, the CNAIM is fully aligned with Toronto Hydro's RCM, meaning that the likelihood that condition variables required by the new ACA model will not be captured during field inspections is low. For more information on Toronto Hydro's RCM, refer to Exhibit 2B, Section D1.2.2.4 and Section D3.1.1.1.

Toronto Hydro determined the condition variables for each asset class based on the following criteria: deficiencies that lead to an asset failure; deficiencies that lead to a component of the asset failing; and deficiencies that degrade the performance of an asset but do not lead to an immediate asset or component failure. The utility performed a comparative analysis of these condition points and assigned appropriate calibration values.

RCM was critical to Toronto Hydro's determination of minimum health score limits in CNAIM, known as "collars." If a deficiency that has a collar is noted during an inspection, the CNAIM algorithm checks to see if the final health score value is above the collar value. If the value is not above the collar value, then the health score is replaced with the collar value. In this way, the severity of any deficiency which may lead to asset failure is not dampened by the appearance of less or no degradation for other condition variables. This eliminates one of the limitations of Toronto Hydro's legacy ACA methodology discussed above.

A detailed technical explanation of the CNAIM model, algorithms, and Toronto Hydro's implementation of those algorithms can be found in Appendix A to this document.

c. Implementation Progress to Date

Toronto Hydro has implemented both the *Current Health Score* and *Future Health Score* for the asset classes listed in Tables 2 and 3, below. Table 2 summarizes the *Current Health Score* demographics for each asset class and Table 3 summarizes the *Future Health Score* demographics for these assets in 2024 assuming no interventions.

Table 2: Summary of Current Health Index Distribution.

Asset Class	Current Health Score				
	HI1	HI2	HI3	HI4	HI5
Overhead Gang-Operated Switches	854	27	76	3	9
SCADA-Mate Switches	1,084	1	26	0	8
Wood Poles	68,425	5,777	20,915	10,877	1,074
4kV Oil Circuit Breakers (MS)	36	4	123	24	0
KSO Circuit Breakers (TS)	10	7	11	11	1
SF6 Circuit Breakers (TS)	130	6	18	3	3
Vacuum Circuit Breakers (MS & TS)	578	46	13	2	29
Air Magnetic Circuit Breakers (MS & TS)	145	90	247	21	53
Airblast Circuit Breakers (MS & TS)	15	9	206	1	3
Station Power Transformers	83	77	61	13	8
Network Transformers	1,334	255	166	60	7
Network Protectors	1,086	185	319	74	26
Cable Chambers	8,112	1,162	1,350	398	89
Submersible Transformers	7,816	588	271	172	55
Air-Insulated Padmount Switches	404	20	73	30	45
Vault Transformers	6,807	4,315	450	214	45
Underground Vaults (combined)	1,017	186	72	12	29
ATS Vaults	8	0	0	0	0
CLD Vaults	21	0	0	0	0
CRD Vaults	9	0	1	0	0
Network Vaults	322	120	63	11	29
Submersible Switch Vaults	115	5	0	0	0
URD Vaults	542	61	8	1	0
Padmount Transformers	5,547	656	283	113	18
SF6-Insulated Padmount Switches	402	0	2	0	6
SF6-insulated Submersible Switches	353	14	7	3	19
Air-Insulated Submersible Switches	755	79	27	7	0

Table 3: Summary of Future Health Index in 2024.

Asset Class	Future Health Score (2024)				
	HI1	HI2	HI3	HI4	HI5
Overhead Gang-Operated Switches	712	135	22	41	59
SCADA-Mate Switches	1,015	43	27	0	34
Wood Poles	59,851	8,767	4,177	17,449	16,824
4kV Oil Circuit Breakers (MS)	36	0	6	119	26
KSO Circuit Breakers (TS)	1	9	7	10	13
SF6 Circuit Breakers (TS)	127	3	4	5	21
Vacuum Circuit Breakers (MS & TS)	575	3	5	54	31
Air Magnetic Circuit Breakers (MS & TS)	97	48	57	277	77
Airblast Circuit Breakers (MS & TS)	3	12	21	194	4
Station Power Transformers	75	25	58	62	22
Network Transformers	1,153	173	229	102	165
Network Protectors	1,027	57	47	177	382
Cable Chambers	6,829	1,546	1,931	327	478
Submersible Transformers	7,447	364	537	143	411
Air-Insulated Padmount Switches	371	30	20	6	145
Vault Transformers	5,397	1,623	3,910	491	410
Underground Vaults (combined)	960	70	162	85	39
ATS Vaults	7	1	0	0	0
CLD Vaults	21	0	0	0	0
CRD Vaults	7	2	0	1	0
Network Vaults	273	55	103	76	38
Submersible Switch Vaults	113	7	0	0	0
URD Vaults	539	5	59	8	1
Padmount Transformers	5174	345	605	227	266
SF6-Insulated Padmount Switches	402	0	0	0	8
SF6 insulated Submersible Switches	346	9	12	4	25
Air Insulated Submersible Switches	710	55	69	23	11

Toronto Hydro does not produce health scores for all major asset classes. The exclusion of an asset class from the ACA is typically due to one of two reasons: (1) it is technically infeasible to collect condition data without damaging the asset; or (2) Toronto Hydro has not developed or fully carried out an advanced inspection program that will provide the inputs necessary to calculate the health score.

Underground cables are an example of the first case described above. Historically, Toronto Hydro has not introduced a cable testing program because the testing methods themselves would shorten the life of the asset. More recently, Toronto Hydro has adopted a new approach and is in the process of implementing it. If successful, the utility will consider using cable testing information to develop an ACA algorithm for cables.

Pole top transformers are an example of an asset for which Toronto Hydro does not presently have a sufficiently advanced, dedicated inspection program. Toronto Hydro performs a cursory inspection of pole top transformers during routine overhead line patrols, checking for any major, readily visible deficiencies. These defects are noted for consideration in reactive and corrective program planning, but the data is not substantial enough to form the basis of a complete ACA algorithm.

d. ACA Integration in CIR Framework

Toronto Hydro's new ACA is a significant part of the utility's 2020-2024 DSP. The utility has leveraged the improved information, including asset condition projections, to help demonstrate the appropriate pacing of planned asset replacement strategies over the forecast period. As mentioned in the introductory sections of this document, a robust ACA can serve as a strong leading indicator of future system performance, including the reliability and safety outcomes that matter most to customers. By gaining better visibility into the overall condition demographics of its major assets, Toronto Hydro has been able to validate and refine its expenditure plans to address assets at a pace that aligns with current and future system needs and customer preferences.

As explained in Section C of the DSP Toronto Hydro has proposed to track and report on a new metric, System Health – Asset Condition (Poles), for the 2020-2024 period. The measure is focused on the percentage of wood poles that are in HI4 or HI5 condition. Since the introduction of an annually reported System Health metric using an adjusted CNAIM methodology is a new development for Toronto Hydro and the Ontario distribution sector in general. As such, additional maturation is still required to enable the projection of Future Health Scores. Toronto Hydro therefore proposes to report on the percentage of wood pole assets in HI4 or H5 category each year through the 2020 to 2024 period and to use the five-year actual data to determine a baseline against which future performance may be measured. This approach is consistent with the OEB's current approach to performance measurement.

e. Areas for Continuous Improvement

(i) Average Age Values

As a step toward refining the accuracy of the model, EA Technology recommended Toronto Hydro undertake a review of its asset useful life values (i.e. minimum expected useful life, maximum expected useful life, and typical useful life for each asset class type). Over time, Toronto Hydro has made minor adjustments to these values based on utility experience, but has not performed a full review of its useful life values (including review of the derivation methodology) since the Kinectrics study performed in 2010.[2] Toronto Hydro intends to update its useful life values and age-based probability of failure curves in the future.

(ii) Location Factor

As mentioned above, the Ofgem algorithm uses location factors values (such as Distance to Coast, Altitude Factor and Corrosion Factor) to determine the expected life of assets. While these factors are suitable to the conditions in the U.K., they may not be suitable for the environmental conditions in Toronto. Toronto Hydro has currently defaulted these values to one and is engaged on developing better condition criteria that will account for the effects of Toronto's environment on the asset deterioration process.

(iii) Reliability Modifier

CNAIM provides for a reliability modifier that can help the utility differentiate subgroups within a specific asset class, e.g. different manufacturers and designs. Currently this has been set to a default neutral value of one. Toronto Hydro requires more information to determine the appropriate scoring of this factor for the algorithm. More data can be collected from field inspections and asset failure resulting in outage events which can be leveraged to develop the reliability modifier.

[2] Kinectrics Inc., *Asset Depreciation Study for the Ontario Energy Board* (July 8, 2010).

Appendix A – Explanation of the Methodology

Introduction

Toronto Hydro's model is similar to Ofgem's CNAIM with minor customizations to fit Toronto Hydro's asset classes. Figure 1 illustrates the methodology, followed by additional details on the major inputs and calculations.

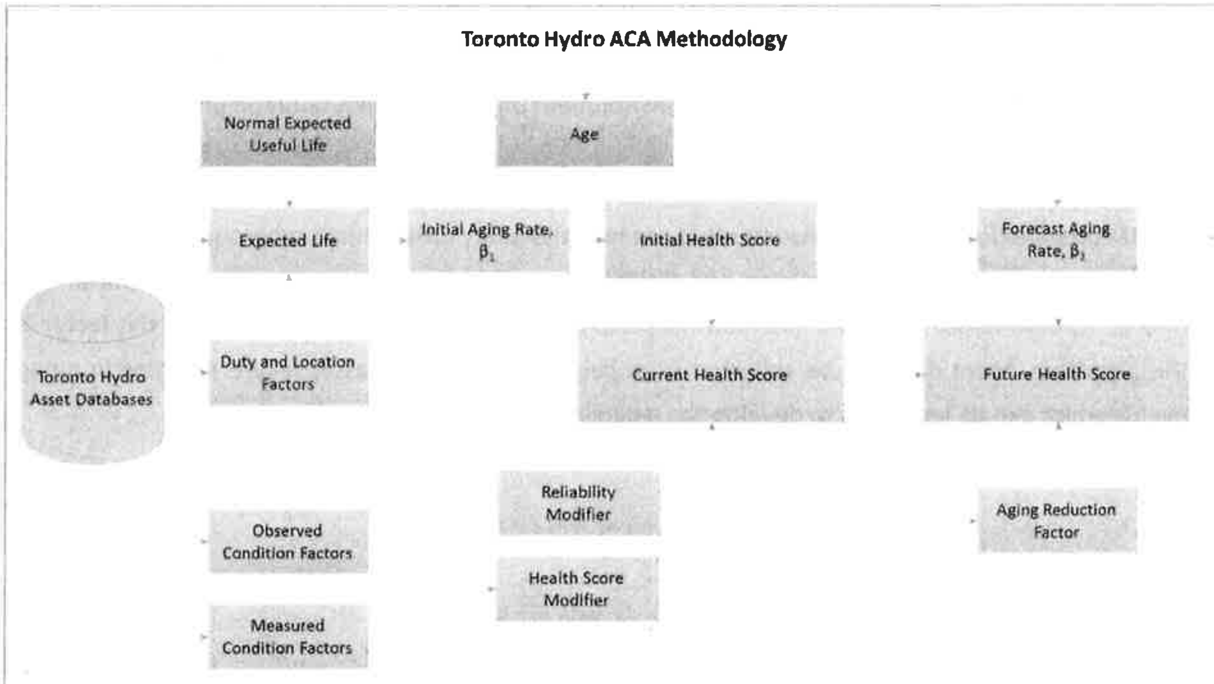

Figure A1: Flow Chart of Toronto Hydro's ACA methodology

Inputs

Inputs such as asset inspection data, nameplate details, location and duty information is provided to the ACA algorithm, from Toronto Hydro's enterprise resource planning (Ellipse) and GIS (GEAR) databases.

Normal Expected Useful Life

The *Normal Expected Useful Life* of an asset is the mid-point between the Minimum and Maximum Useful Life for the asset from the Kinectrics study and is generally aligned with current Toronto Hydro organization-wide practices.

Expected Life

The *Expected Life* of an asset is the *Normal Expected Useful Life* for the asset group adjusted to account for the asset's specific operating conditions (i.e. its environment and the way it is used) as shown in Equation 1.

$$Expected\ Life = \frac{Normal\ Expected\ Useful\ life}{(Duty\ Factor * Location\ Facor)} \quad \text{Eq. 1}$$

Where *Location Factor* and *Duty Factor* are as described below.

Location Factor

Location Factors account for the environmental conditions in which an asset operates. As conditions in Toronto differ from the U.K., factors used by Ofgem are not necessarily suitable for use by Toronto Hydro. Therefore, Toronto Hydro is currently working on developing the *Location Factor* condition criteria for its assets. Currently, the *Location Factor* value is defaulted to one for all assets.

Duty Factor

The *Duty Factor* is applied to account for the fact that the expected life of an asset varies depending on the way it is used, i.e. its duty. The CNAIM allows for an asset to have two different duties, but Toronto Hydro only included one *Duty Factor* based on the available inputs for its assets. Table 4 shows the basis on which *Duty Factors* are assigned for each asset category, as they are defined differently depending on the type of asset. Appendix B provides additional detail on how specific *Duty Factor* values are assigned to assets based on the variables in Table 4.

Table B11: Vault Transformers – Oil Leak (Base)

	Condition Input Factor	Condition Input Cap	Condition Input Collar
As New	0.9	10	0.5
Good	1	10	0.5
Slight Leak	1.25	10	6
Poor	1.35	10	7
Very Poor	1.5	10	9
Default	1	10	0.5

Table B12: Vault Transformers – Connection Condition

	Condition Input Factor	Condition Input Cap	Condition Input Collar
As new	0.9	10	0.5
Normal Wear	1	10	0.5
Some Deterioration	1.12	10	0.5
Substantial Deterioration	1.25	10	0.5
Default	1	10	0.5

Table B13: Vault Transformers – External Condition of Tank (Transformer Body)

	Condition Input Factor	Condition Input Cap	Condition Input Collar
As New	0.9	10	0.5
Good	1	10	0.5
Slight Deterioration	1.02	10	0.5
Poor	1.1	10	4
Very Poor	1.2	10	6.5
Default	1	10	0.5

Table B14: Vault Transformers – Oil Leak (Not Base)

	Condition Input Factor	Condition Input Cap	Condition Input Collar
As New	0.9	10	0.5
Good	1	10	0.5
Slight Leak	1.1	10	4
Poor	1.2	10	5.5
Very Poor	1.25	10	6
Default	1	10	0.5

The Health Index Bands in the new and old ACA methodologies are not similar and do not allow for a one-to-one comparison. Both methodologies have five health categories that are intended to track the condition-based probability of failure of an asset, but they are underpinned by different calculations. Table 2 below summarises the benefits of the new ACA methodology compared to the old methodology, as described in the Toronto Hydro Asset Condition Assessment Methodology report (Exhibit 2B, Section D, Appendix C).

Table 2. General Comparison between the Old and New ACA Methodologies.

Weighted Arithmetic Summation Model	Toronto Hydro's Implementation of CNAIM Methodology
The model lacks a formal, mathematical link between the condition of an asset and its probability of failure.	Stronger and more objective relationship between condition and probability of failure.
Critical conditions that can lead to total asset failure, even if assigned a higher weighting, can be masked by the combination of all other benign condition attributes. This dynamic dilutes the relationship between the HI scores and asset failure risk, with a structural bias toward understating the magnitude of deterioration in an asset's health.	Robust scoring methodology emphasizing deficiencies that directly impact equipment failure.
Rejects assets with less than 60% of the condition data, resulting in a large number of assets being excluded.	Fewer asset exclusions due to data availability.
No future modeling of the condition of assets, which is an important means of assessing the pacing and effectiveness of a utility's investment plans.	The ability to project future asset health scores, providing strategic insight into longer-term investment strategies using forecasted HI demographics.

Table 3 and Figure 1 below provide additional support for the second point in Table 1 above. Table 3 compares the health indices of assets with certain deficiencies under the two methods. This demonstrates that the new ACA methodology accurately depicts the

RESPONSES TO ASSOCIATION OF MAJOR POWER CONSUMERS IN ONTARIO INTERROGATORIES

INTERROGATORY 20:

Reference(s): **Exhibit 2B, Section A4, p. 10**

THESL indicates the most significant driver of investment in Toronto Hydro's DSP is asset failure and failure risk due to a continuing backlog of deteriorating and obsolete assets. (other drivers)

a) Please provide the asset classes that THESL has multi-year failure data for.

b) Does THESL track the age an asset fails for all asset classes?

RESPONSE:

a) Toronto Hydro captures this information for the following major asset classes:
   - Overhead Transformers
   - Overhead Switches
   - Poles
   - Cable Chambers
   - Network Protector
   - Underground Switches
   - Underground Transformers
   - Vaults
   - Station Transformers
   - Station Battery

- Station Air Compressor
- Station Switchgear
- Station Circuit Breaker

b) The age an asset fails is not tracked for all asset classes. Toronto Hydro aims to capture this information when the failed asset is removed from service through the utility's quality programs in Standards and Policies. Please refer to Exhibit 4A, Tab 2, Schedule 9.

Useful Lives

RESPONSES TO OEB STAFF INTERROGATORIES

INTERROGATORY 139:

Reference(s): **Updated Exhibit 4B, Tab 1, Schedule 1, p. 2-4**
Exhibit 4B, Tab 1, Schedule 1, Appendix A
Updated Exhibit 4B, Tab 1, Schedule 1, Appendix C

a) For the asset categories that Toronto Hydro proposed Useful Life (ULs) outside the Kinectrics range, please provide supporting rationale (Updated Exhibit 4B / Tab 1 / Schedule 1 / Appendix C).

b) Please explain how Toronto Hydro accurately forecasts, over a 5-year period, the particular month in which an asset will enter service (Exhibit 4B / Tab 1 / Schedule 1 / pp. 3-4).

c) Please provide detailed working papers (showing the monthly data) supporting the depreciation expense schedule (Exhibit 4B / Tab 1 / Schedule 1 / Appendix A).

RESPONSE:

a) As allowed by the OEB,[1] Toronto Hydro adopted useful lives (in some cases) that are outside the range of 'Asset Depreciation Study for the Ontario Energy Board' by Kinectrics ("OEB Study"). A list and additional information follows:

[1] EB-2008-0408, Report to the Board, Transition to International Financial Reporting Standards, Page 21.

	USoA Account Number	USoA Account Description	Current Years	Asset Details: Category| Component | Type	
1	1830	Poles, Towers and Fixtures (Streetlighting)	40	Fully Dressed Concrete Poles	
2	1835	Overhead Conductors and Devices (Streetlighting)	40	OH Conductors	
3	1820	Distribution Station Equipment - Normally Primary Below 50 kV	25	Station Grounding Transformer - Station Grounding System	
4	1820	Distribution Station Equipment - Normally Primary Below 50 kV	30	Station Independent Breakers	
5	1845	Underground Conductors and Devices	20	Primary TR XLPE Cables Direct Buried	
6	1845	Underground Conductors and Devices	20	Secondary Cables Direct Buried	
7	1855	Services (Overhead & Underground)	20		
8	1840	Underground Conduit (Cable Chamber Roof)	20	Cable Chambers	
9	1910	Leasehold Improvements	5	Leasehold Improvements	
	1908	Buildings and Fixtures	20	Administrative Buildings	
	1908	Buildings and Fixtures	30		
10	1808	Buildings and Fixtures	20		
	1808	Buildings and Fixtures	30	Station Buildings	
	1808	Buildings and Fixtures	36		
11	1920	Computer Equipment - Hardware	6	Computer Equipment	Hardware
12	1611	Computer Software	10		Software

Figure 1: Useful Lives

1) For fully dressed street lighting concrete poles (account 1830), Toronto Hydro uses a useful life 40 years while the OEB Study has a useful life of from 50-80 years. Toronto Hydro based its assessment on the THESL sponsored Street Lighting and Expressway Lighting Assets Valuation Report by ValuQuest.[2]

2) For street lighting overhead conductors and devices (account 1835), Toronto Hydro uses a useful life of 40 years while the OEB Study has a useful life of 50-75 years. Toronto Hydro based its assessment on the THESL sponsored study 'Toronto Hydro Electric System Useful Life of Assets' by Kinectrics (THESL Study).[3] The THESL Study was completed in August 2009 (before the OEB Study was issued in July 2010) since THESL was preparing to adopt the IFRS accounting standards.

3) Toronto Hydro uses a useful life of 25 years for Station Grounding System (account 1820) compared to a useful life of 30-40 years as per the OEB Study. Toronto

[2] EB-2009-0180/0181/0182/0183, Application for transfer of Streetlighting Assets, Appendix B, Filed 31st Jan, 2011
[3] EB-2020-0142, Exhibit Q1, Tab 2, Schedule 7-2, Filed 9th Feb, 2011.

Hydro based its assessment on the THESL Study which has the range of 25-50 years.

4) The sub-assets under the category Station Independent Breakers (account 1820) are shown in the table below with the Toronto Hydro's useful lives based on the THESL Study. The OEB Study has a range of 35 to 65 years.

Table 1: Useful Lives based on the THESL Study

Section	Asset	Years
21	Oil Breaker (Outdoor)	30
22	SF6 Breaker (Outdoor)	30
23	Vacuum Breaker (Outdoor)	30
24	Oil Breaker (Indoor)	30
25	SF6 Breaker (Indoor)	30
26	Vacuum Breaker (Indoor)	30
27	Air Blast Breaker (Indoor)	30
28	Air Magnetic Breakers (Indoor)	25

5) Primary TR XLPE Cables Direct Buried (account 1845) contains the underground Primary Cable (XLPE Direct Buried) asset which has a useful life of 20 years compared to the useful life of 25 to 35 years as per the OEB Study. Toronto Hydro based its assessment on the THESL Study which has a range of 20-25 years.

6) The USoA account 1845 Underground Conductors and Devices includes the asset UG Secondary Cable (Direct Buried) which has a useful life of 20 years compared to 25 to 40 years as per the OEB Study. Toronto Hydro based its assessment on the THESL Study which has a range of 20-25 years.

7) The USoA account 1855 Services (Overhead & Underground) includes the asset underground Secondary Cable (Direct Buried) which has a useful life of 20 years compared to a useful life of 25 to 40 years as per the OEB Study. Toronto Hydro based its assessment on the THESL Study which has a range of 20-25 years.

8) Cable chambers roofs included in account 1840 have a useful life of 20 years compared to the OEB Study of 50 to 80 years. Toronto Hydro based its assessment on the THESL Study which has a range of 20-30 years.

9) Toronto Hydro uses a useful life of 5 years for Leasehold Improvements. There is no specific useful life in the OEB Study since, in such cases, useful life are lease dependent.

10) Buildings and Fixtures (accounts 1808 and 1908) have a useful life of 20 to 36 years compare to OEB Study range of 50-75 years. The OEB category does not included many substructure categories that are unique to Toronto Hydro, where the useful life is aligned with a study by Pinchin Environmental Ltd.4

11) Toronto Hydro P-servers have a useful life of six years compared to the range of 3-5 years as per the OEB Study. These are specialized servers that Toronto Hydro assessed internally to have a longer useful life.

12) The Computer Software (account 1611 – 10 years) includes the utility's CIS/Customer Care & Billing (CC&B) computer software. An internal assessment

[4] EB-2010-0142, Exhibit R2, Tab 1, Schedule 4, Filed 2011 Feb 23, Interrogatory Q1-Staff-4

was performed which concluded that, for the CIS, a useful life of 10 years was appropriate.

b) Please refer to Toronto Hydro's response to interrogatory 2A-SEC-31.

c) Please see Appendix A to this response for the monthly historical depreciation expense for 2015-2017. Please see Appendix B to this response for the monthly forecasted depreciation expense for 2018-2024.

Toronto Hydro notes that historical depreciation expense results from detailed calculations within its ERP (financial) system which provides balances by USoA account. For forecasted monthly depreciation expense, which is calculated outside the ERP, balances by USoA account is not available.

RESPONSES TO ASSOCIATION OF MAJOR POWER CONSUMERS IN ONTARIO INTERROGATORIES

INTERROGATORY 42:

Reference(s): **Exhibit 2B, Section D, Appendix C, p. 4**

a) Please provide a copy of the ACA THESL used to underpin the capital plan in EB-2014-0116 application.

b) Please provide a copy of THESL's most recent ACA prior to the change in methodology in 2016 to CNAIM.

RESPONSE:

a) Please refer to Appendix A of this response.

b) **Table 1: 2016 ACA Results Prior To Changing The ACA Algorithm**

		2016 ACA RESULTS (PREVIOUS ALGORITHM)						
No.	**Asset Type**	**Total Population**	**% Sample Size**	**Very Poor (HI < 30)**	**Poor (30 ≤ HI < 50)**	**Fair (50 ≤ HI < 70)**	**Good (70 ≤ HI < 85)**	**Very Good (HI ≥ 85)**
1	**AIRBLAST CIRCUIT BREAKER**	241	75.9%	0.0%	4.4%	88.0%	7.1%	0.6%
2	**PADMOUNT SWITCH (AIR)**	643	94.9%	0.0%	0.0%	4.3%	55.6%	40.2%
3	**AUTOMATIC TRANSFER SWITCH**	39	66.7%	0.0%	0.0%	15.4%	76.9%	7.7%
4	**CABLE CHAMBER**	11132	62.4%	0.2%	2.7%	10.1%	62.4%	24.6%

No.	Asset Type	2016 ACA RESULTS (PREVIOUS ALGORITHM)						
		Total Population	% Sample Size	Very Poor (HI < 30)	Poor (30 ≤ HI < 50)	Fair (50 ≤ HI < 70)	Good (70 ≤ HI < 85)	Very Good (HI ≥ 85)
5	AIRMAGNETIC CIRCUIT BREAKER	562	89.7%	0.2%	6.2%	74.4%	16.9%	2.4%
6	NETWORK PROTECTOR	1683	98.2%	0.0%	0.1%	27.5%	12.5%	59.8%
7	NETWORK TRANSFORMER	1821	98.2%	0.0%	0.1%	7.1%	42.2%	50.6%
8	NETWORK VAULT	1055	99.6%	0.0%	0.9%	32.5%	66.6%	0.0%
9	4KV OIL CIRCUIT BREAKER	198	74.2%	0.0%	12.9%	79.6%	7.5%	0.0%
10	KSO- OIL CIRCUIT BREAKER	46	84.8%	0.0%	7.7%	74.4%	18.0%	0.0%
11	OVERHEAD GANG OPERATED SWITCH	1071	54.0%	0.0%	0.2%	1.0%	70.4%	28.4%
12	PADMOUNT TRANSFORMER	7496	88.6%	0.0%	0.0%	6.8%	79.3%	13.9%
13	SCADAMATE SWITCH R2	1114	93.7%	0.0%	0.0%	0.9%	41.8%	57.4%
14	SF6 CIRCUIT BREAKER	174	70.7%	0.0%	0.0%	19.5%	65.0%	15.5%
15	STATION TRASNSFORMER	292	89.7%	0.0%	0.4%	26.7%	49.6%	23.3%
16	SUBMERSIBLE TRANSFORMER	9244	97.9%	0.0%	0.5%	8.6%	33.1%	57.9%
17	VACUUM CIRCUIT BREAKER	661	81.4%	0.0%	0.2%	4.8%	42.2%	52.8%
18	VAULT TRANSFORMER	13283	91.5%	0.0%	1.0%	28.4%	42.0%	28.7%
19	WOOD POLE	125899	67.3%	1.5%	1.4%	15.6%	19.6%	61.9%

EB-2018-0165

AMPCO ACA Table - Panel 1

2B-AMPCO-42 (a) ACA from EB-2014-0116

Asset	Population	# very poor	# poor	# fair	# good	# very good	Total	# very poor & poor	# very poor, poor & fair
1 Station Power Transformer	268	3	37	133	62	33	268	40	173
2 Station Switchgear	279	14	102	93	26	44	279	116	209
3 Air Blast Circuit Breakers	290	0	11	255	8	16	290	11	266
4 Air Magnetic Circuit Breakers	627	1	30	466	118	12	627	31	496
5 Oil Circuit Breakers	332	2	34	275	21	0	332	36	311
6 Oil KSO Breakers	59	0	3	48	8	0	59	3	51
7 SF6 Circuit Breaker	201	0	0	15	93	93	201	0	15
8 Vacuum Circuit Breakers	675	0	1	21	69	583	675	1	23
9 Submersible Transformers	9554	0	2	638	3337	5576	9553	2	640
10 Vault Transformers	13034	0	30	3060	5188	4757	13035	30	3090
11 Padmounted Transformers	7160	0	1	722	3115	3321	7160	1	724
12 Padmounted Switches	802	0	3	58	290	452	802	3	61
13 3 Phase O/H Gang Manual Switches	1108	0	4	33	707	367	1112	4	38
14 3 Phase O/H Gang Remote Switches	15	0	0	2	12	1	15	0	2
15 SCADAMATE Switches	926	1	0	11	531	383	926	1	12
16 Wood Poles	123280	2885	9419	54403	8975	47598	123280	12303	66707
17 Automatic Transfer Switches	58	0	10	19	18	12	58	10	28
18 Network Transformers	1892	0	0	310	784	797	1892	0	310
19 Network Protectors	1615	0	0	61	521	1034	1615	0	61
20 Network Vaults	1062	18	93	769	171	11	1062	112	880
21 Cable Cambers	10902	28	174	1174	5470	4056	10902	203	1377
TOTAL	174139							12907	75474
								7%	

2B-AMPCO-42 (b) 2016 ACA

Asset	Population	# very poor	# poor	# fair	# good	# very good	Total	# very poor & poor	# very poor, poor & fair
1 Station Power Transformer	292	0	1	78	145	68	292	1	79
2 Station Switchgear									
3 Air Blast Circuit Breakers	241	0	11	212	17	1	241	11	223
4 Air Magnetic Circuit Breakers	562	1	35	418	95	13	563	36	454
5 Oil Circuit Breakers	198	0	26	158	15	0	198	26	183
6 Oil KSO Breakers	46	0	4	34	8	0	46	4	38
7 SF6 Circuit Breaker	174	0	0	34	113	27	174	0	34
8 Vacuum Circuit Breakers	661	0	1	32	279	349	661	1	33
9 Submersible Transformers	9244	0	46	795	3060	5352	9253	46	841
10 Vault Transformers	13283	0	133	3772	5579	3812	13296	133	3905
11 Padmounted Transformers	7496	0	0	510	5944	1042	7496	0	510
12 Padmounted Switches	643	0	0	28	358	258	644	0	28
13 3 Phase O/H Gang Manual Switches	1071	0	2	11	754	304	1071	2	13
14 3 Phase O/H Gang Remote Switches									
15 SCADAMATE Switches	1114	0	0	10	466	639	1115	0	10
16 Wood Poles	125899	1888	1763	19640	24676	77931	125899	3651	23291
17 Automatic Transfer Switches	39	0	0	6	30	3	39	0	6
18 Network Transformers	1821	0	2	129	768	921	1821	2	131
19 Network Protectors	1683	0	2	463	210	1006	1681	2	465
20 Network Vaults	1055	0	9	343	703	0	1055	9	352
21 Cable Cambers	11132	22	301	1124	6946	2738	11132	323	1447
TOTAL	176654							4246	32043
								2%	

A4.1.1 System Challenges: Deteriorating and Obsolete Assets

The most significant driver of investment in Toronto Hydro's DSP is asset failure and failure risk due to a continuing backlog of deteriorating and obsolete assets. A key system-wide indicator of the magnitude of this challenge is the percentage of Assets Past Useful Life ("APUL"). As seen in Figure 3, below, approximately a quarter of the utility's asset base is operating beyond useful life, and an estimated 9 percent will reach that point by 2025, indicating that a significant proactive renewal program is necessary to prevent this backlog from increasing. An increase in the APUL backlog would likely result in a corresponding deterioration in reliability, safety and other outcomes driven by asset failure and failure risk.

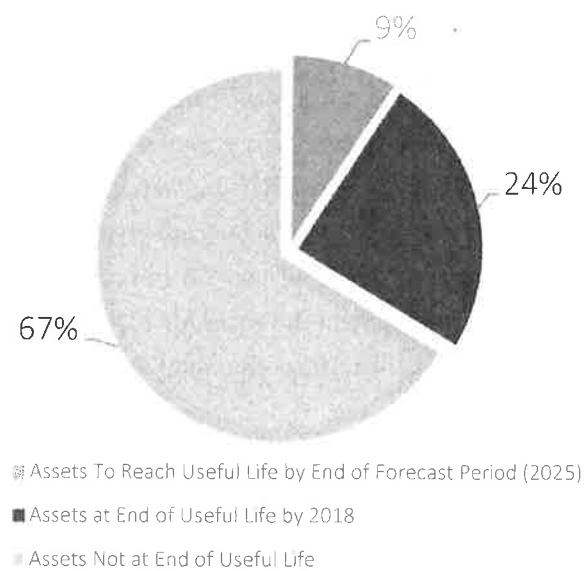

Figure 3: Percentage of Assets Past Useful Life

Asset Condition Assessment ("ACA") demographic results also indicate substantial asset investment needs for a number of critical asset classes over the plan period. Among the subset of asset classes analyzed using Toronto Hydro's ACA methodology, major civil assets like poles and vaults, which are the backbone of a safe and viable distribution system, and major stations electrical assets, which have the highest potential reliability impact on the system, are showing the greatest signs of material deterioration.

As explained in the System Renewal program justifications in Section E6, Toronto hydro is proposing a pace of renewal investment in a number of core programs that is the minimum required to prevent these age and condition-related risks from worsening over the 2020-2024 period. For instance, without the proposed proactive intervention in the overhead asset class, Toronto Hydro projects that the percentage of pole top transformers having reached or exceeded useful life will increase from 14 percent as of 2017 to approximately 40 percent by 2024, and the number of poles with material deterioration could nearly triple to over 30,000.

The utility also continues to face challenges related to higher-risk, obsolete, legacy assets, and asset configurations such as rear lot plant, box construction, non-submersible network equipment, and direct-buried cable. Legacy assets are specific asset types, configurations, or sub-systems that do not meet current Toronto Hydro standards, often featuring obsolete components with limited or no suppliers or skilled labour to support maintenance, repair, or replacement. Due to asset-specific defects or deficiencies, these assets typically carry elevated reliability, safety, or environmental risks. For example, direct-buried cable and non-submersible network protectors are highly susceptible to moisture-related damage and continue to be significant contributors to reliability and safety risk. Another example is transformers at risk of spilling PCB-contaminated oil. Toronto Hydro's pole-top and underground transformer replacement strategies for 2020-2024 are driven in part by the utility's efforts to effectively eliminate this critical environmental risk over the period.

Toronto Hydro has seen improvements in the frequency and duration of outages caused by defective equipment. However, defective equipment continues to be, by far, the largest contributor to outage frequency (i.e. SAIFI), at 36 percent, and outage duration (i.e. SAIDI), at 44 percent. In light of the age, condition, and legacy asset risks discussed above, Toronto Hydro concludes that a shift to a more reactive renewal approach would result in a decline in reliability over the short- and long-term, with potentially significant impacts for customers in areas served by legacy assets such as direct-buried cable and rear-lot plant. A reactive renewal approach would also be more costly over the long-term.

A4.1.2 System Challenges: Climate Change and Adverse Weather

On top of the reliability challenges posed by a backlog of deteriorating and obsolete equipment, Toronto Hydro anticipates that increasingly frequent adverse and extreme weather events will put additional reliability pressures on the system, making the resiliency of the system and the utility's operations a greater concern over the medium- to long-term than in past planning cycles.

RESPONSES TO ASSOCIATION OF MAJOR POWER CONSUMERS IN ONTARIO INTERROGATORIES

INTERROGATORY 21:

Reference(s): **Exhibit 2B, Section A4, p. 10, Figure 3**

THESL indicates that as of the end of 2017, approximately 24 percent of assets will be in-service past their useful life, as shown in Figure 3 below.

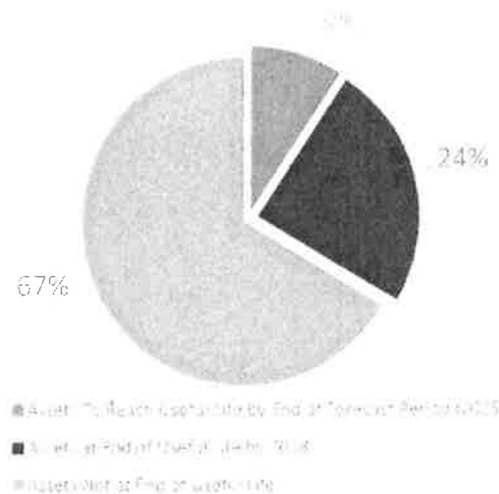

Figure 3: Percentage of Assets Past Useful Life

a) Please provide the calculation that underpins the percentages in Figure 3.

b) Please provide a pie chart that shows the Percentage of Assets with Health Index Scores of H14 and HI5 by 2018; Percentage of Assets with Health Index Scores of H14 and HI5 at the end of Forecast Period (2025); and Percentage of Assets that do not have a Health Index Score of H14 or HI5.

c) Please provide the calculation that underpins part b).

RESPONSE:

a) Please refer to Toronto Hydro's response to interrogatory 1B-CCC-12.

b) The following figure shows the percentage of assets in HI4 or HI5 condition as of the end of 2017 and the percentage of additional assets forecasted to be in HI4 or HI5 condition by 2025. Please note that this chart pertains only to the subset of asset classes for which Toronto Hydro calculates Health Scores (i.e. assets for which Toronto Hydro does not calculate health scores (e.g. cables; pole-top transformers) are excluded from the chart.

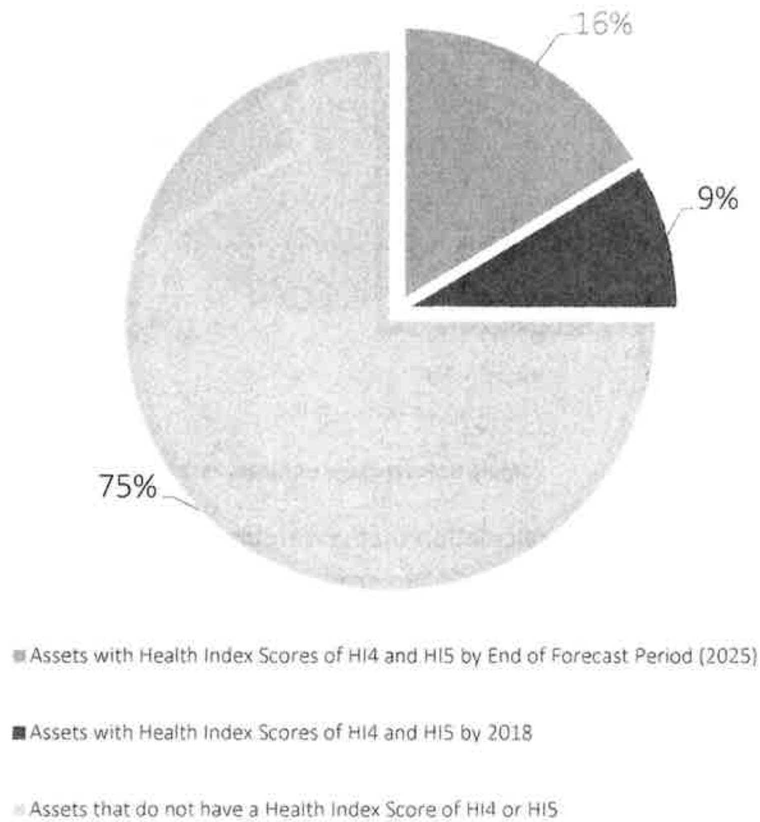

Figure 1: Percentage of Assets with Health Index Scores of HI4 or HI5

c) The data used to produce Figure 1 in part (b) above is based on the Current Health Index distribution (as of the end of 2017) provided in Exhibit 2B, Section D, Appendix C, Table 2 and the Future Health Index distribution (by 2025), provided in Exhibit 2B, Section D, Appendix C, Table 3. The 9 percent value is the current proportion of assets in HI4 and HI5. The 16 percent value is the additional proportion projected to be in HI4 and HI5 by 2025.

TECHNICAL CONFERENCE UNDERTAKING RESPONSES TO ASSOCIATION OF MAJOR POWER CONSUMERS IN ONTARIO

UNDERTAKING NO. JTC2.14:

Reference(s): **Exhibit 2B, Section E2, page 12**

To provide the calculation of the denominator or, in other words, the total number of the asset population used to derive the pie chart.

RESPONSE:

Toronto Hydro follows the approach outlined in the response to interrogatory 1B-CCC-12 to calculate the percentage at and past the Mean Useful Life for each asset class or type. The total asset population is translated to a replacement value in order to establish a system level metric for use as a strategic indicator.[1]

The denominator used to calculate the percentage of assets past useful life is approximately $9.5 billion. The value of assets at end of useful life (numerator) is approximately $2.3 billion. This results in the 24% of assets at end of useful life by 2018.

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[1] Note that this addresses the question from Dr. Lowry on page 77 of the transcript from Day 4 of the Technical Conference (EB-2018-0165 THESL Technical Conference Friday, February 22, 2019).

2018-20 Corporate Business Plan

Board of Directors Meeting

November 23, 2017

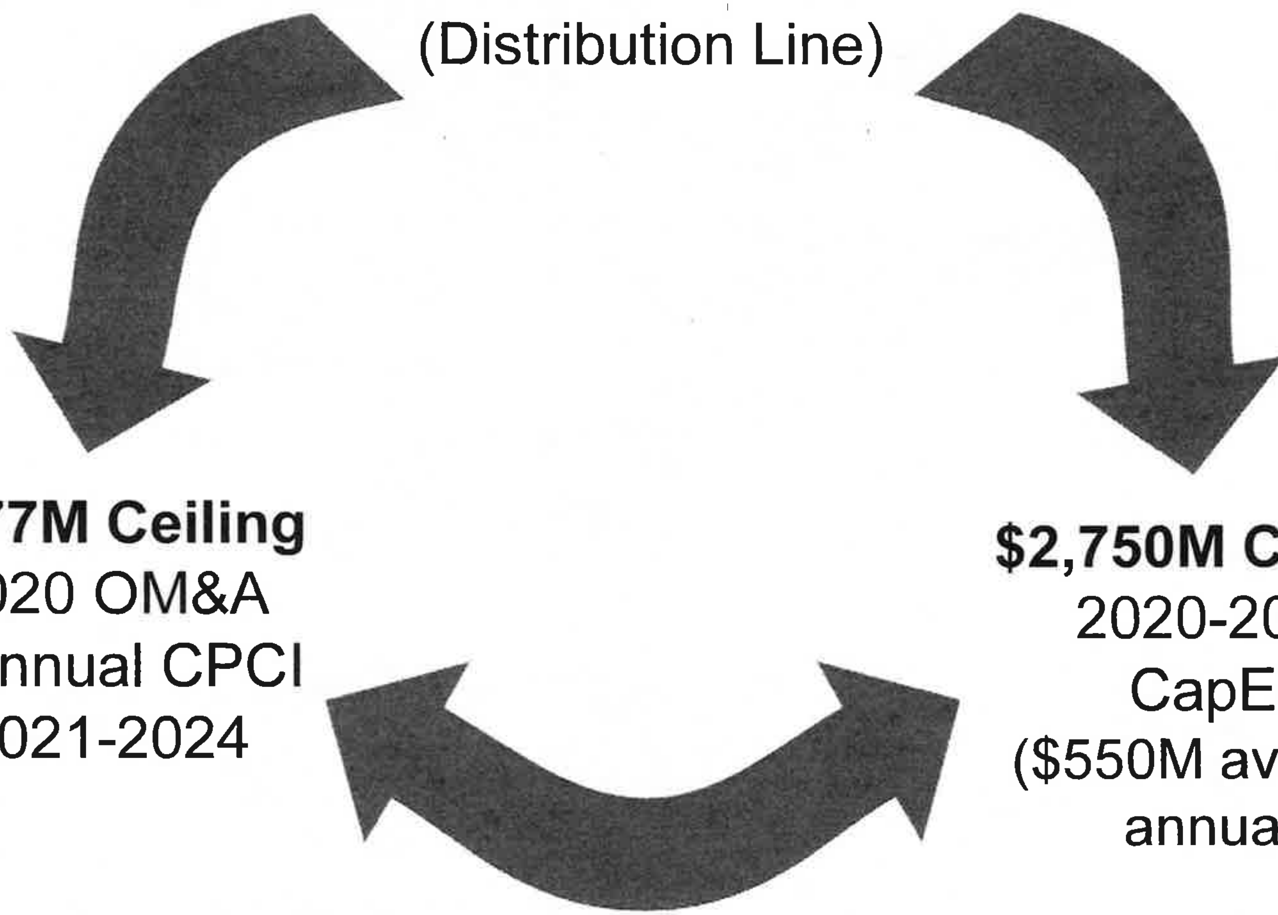
Draft for review and approval

This report contains confidential, financial, commercial and/or technical information that belongs to Toronto Hydro. The report has not been made public, has had limited circulation within Toronto Hydro and has been continuously treated as confidential. As it is reasonable to expect that the disclosure of the information in this report at this time could prejudice the competitive position of Toronto Hydro and be injurious to its interests and further, could result in undue gain to a third party at the expense of Toronto Hydro or another organization, any copying, disclosure or other distribution of this report or its content by members of the Board strictly prohibited.

TORONTO HYDRO®

Regulatory Application

3.5% Ceiling
Average Annual
Rate Increase
(Distribution Line)

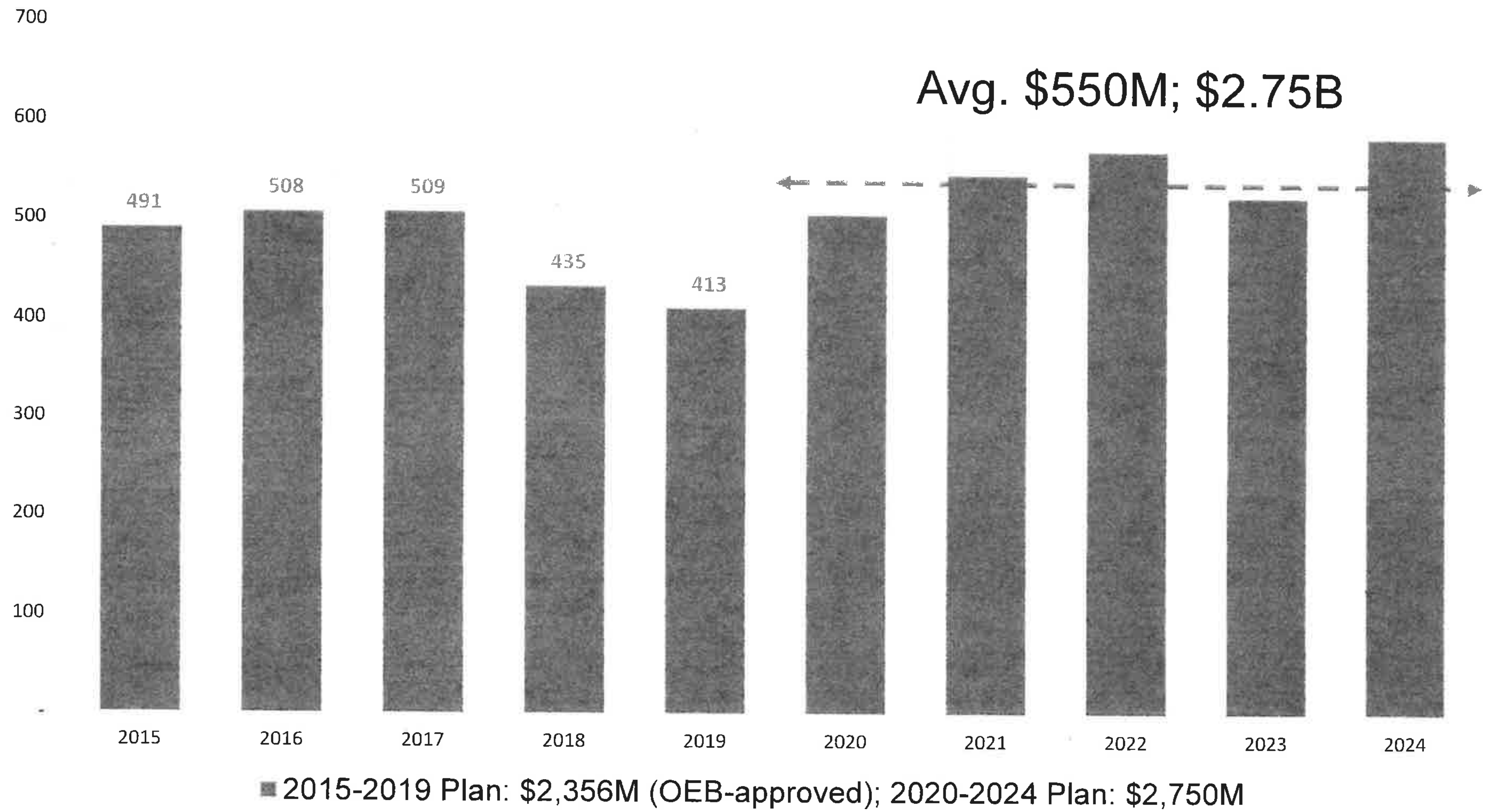


$277M Ceiling
2020 OM&A
+ Annual CPCI
2021-2024

$2,750M Ceiling
2020-2024
CapEx
($550M average
annual)

48

Regulated Capital Program



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RESPONSES TO CONSUMERS COUNCIL OF CANADA INTERROGATORIES

INTERROGATORY 12:

Reference(s): **Exhibit 1B, Tab 1, Schedule 1, p. 11**

The evidence states that 24% of the utility's asset base continues to operate beyond useful life, and an estimated 9% will reach that point by 2025. Please explain how these numbers were calculated. Specifically, what process does THESL use to determine whether assets are beyond their useful life? How does THESL define "beyond useful life"?

RESPONSE:

Unless otherwise specified, the term "Useful Life" used throughout Toronto Hydro's application refers specifically to an asset's Mean Useful Life ("Mean UL").

Derivation of Mean Useful Life

For each of its major system asset types, Toronto Hydro derives a Mean UL from the estimated Useful Life Ranges provided in the 2009 Kinectrics report, "Toronto Hydro-Electric System Useful Life of Assets".[1] The Useful Life Range is defined in part by a Minimum Useful Life ("MIN UL") and a Maximum Useful Life ("MAX UL"), where the MIN UL is "the age when a small percentage of assets reaches physical end-of-life" and "the failure rate starts increasing exponentially," and the MAX UL is the "age when most assets reach physical end-of-life." The Mean UL is the "arithmetic average value of the end-of-life year data" and is equal to the mid-point between the MIN UL and MAX UL.[2]

---

[1] Toronto Hydro has provided a copy of this report as Appendix A to its response to interrogatory 2B-SEC-38.

[2] Kinectrics Report, "Asset Depreciation Study for the Ontario Energy Board" (July 8, 2010) at pages 10 and 159.

Assessing Assets Past Useful Life

Toronto Hydro considers an asset to be operating "beyond" or "past useful life" if it remains in service at an age that is greater than its Mean UL. Toronto Hydro calculates the percentage of Assets Past Useful Life ("APUL") by comparing the age demographics of its asset population to the Mean UL for each asset class or type.

Please refer to Exhibit 2B, Section E2.2.2.1 for additional information about the Assets Past Useful Life (APUL) metric.

TECHNICAL CONFERENCE UNDERTAKING RESPONSES TO ASSOCIATION OF MAJOR POWER CONSUMERS IN ONTARIO

UNDERTAKING NO. JTC3.21:

Reference(s): 1B-SEC-9

To review and consider whether to disclose a copy of the maintenance and stations capital audit; if not, to advise why not.

RESPONSE:

Toronto Hydro notes that AMPCO requested[1] copies of reports pertaining to all four internal audit activities identified in the response to interrogatory 4A-AMPCO-97(a).

A copy of the Maintenance and Station Capital Audit Report is attached as Appendix A to this response. Toronto Hydro does not have audit reports for the other three activities noted the interrogatory response for the reasons that follow.

The SAP Implementation Review is an internal monitoring activity for the ongoing Enterprise Resource Planning ("ERP") system upgrade project. This work is ongoing as part of the Post-Implementation phase of the ERP project, and as such a final audit report has not been completed.

Internal Controls Over Financial Reporting audits are performed annually and any resulting observations are presented to the Audit Committee of Toronto Hydro

[1] EB-2018-0165 Technical Conference Transcript Day 3, page 146, lines 15-16.

Corporation's Board of Directors, when the Committee convenes. These are no audit reports generated as part of this activity.

Special Consulting & KPMG Support refers to the annual activities undertaken by internal audit to support the work of the external auditors. There are no reports generated as part of this activity.

These processes and activities can result in both capital and operating expenditures (e.g. corrective tree trimming). The Corrective Maintenance program (Exhibit 4A, Tab 2, Schedule 4) is the operational counterpart to the Reactive Capital segment.

Toronto Hydro has an established internal process for reviewing all work inquiries from these sources to validate the need for reactive intervention, assess the nature of reactive intervention required (i.e. capital versus maintenance), and the level of urgency/priority to be assigned to each item. Prioritization of the asset deficiencies identified as part of the work request process is based on the urgency of the work and how quickly it needs to be resolved. The work requests are classified into three categories (P1, P2, and P3) as discussed in Section D3.2.1.3 and illustrated in Figure 2:

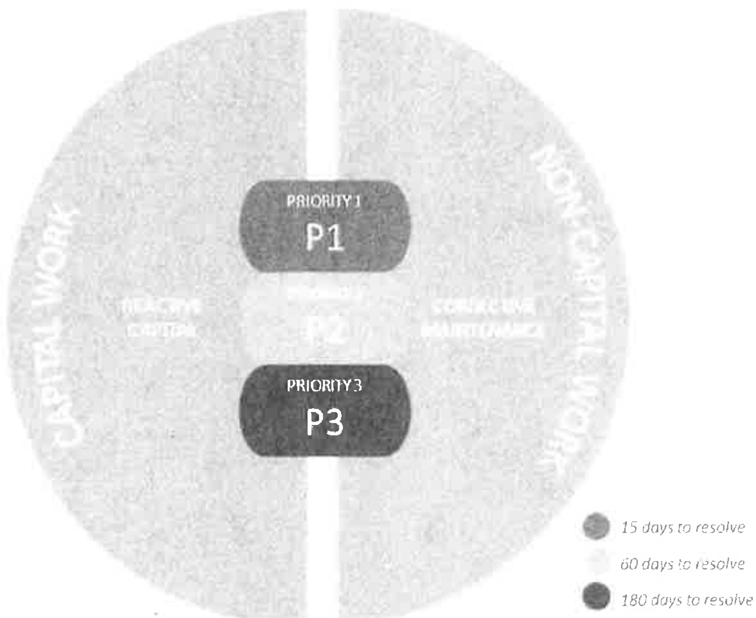

Figure 2: Work Request Prioritization

D3.1.1.3 Impact of System Renewal on Maintenance Planning

Toronto Hydro routinely assesses the impact of its system renewal investments on preventative and predictive maintenance plans. The directional relationship between asset replacement and planned maintenance is largely dependent on the maintenance requirements for the assets being removed and installed.

deficiencies identified during the course of utility operations (and not just defective equipment deficiencies). That process has three categories of priorities:

- **P1**, requiring a resolution within 15 days;
- **P2**, requiring a resolution within 60 days; and
- **P3**, requiring a resolution within 180 days.

A P1 is assigned to defective equipment that has a DETS score greater than 100 and a P2 is assigned to defective equipment that has a score less than 100. Analysis of the DETS scores and the volumes of priority deficiencies provides Toronto Hydro with another layer of risk modelling and inputs for risk management.

For additional details related to deficiencies, defective equipment, and prioritized reactive and corrective actions, please see the Reactive and Corrective Capital (Exhibit 2B, Section E6.7), Corrective Maintenance (Exhibit 4A, Tab 2, Schedule 4), and Emergency Response (Exhibit 4A, Tab 2, Schedule 5) programs.

6. Legacy Assets

Toronto Hydro's risk assessment frameworks include inventories of legacy assets and configurations that have been identified based on various factors (e.g. their likelihood of failure and resulting impact on system reliability, safety, or the environment). These assets and configurations are also typically functionally obsolete with limited or no support from manufacturers or third party service providers. Toronto Hydro monitors these legacy assets to manage and minimize their associated risks to customers, employees, and the public. The utility evaluates legacy asset risk and performance over time, adjusting investment plans over the short-, medium- and long-term to ensure the risks are being addressed at an appropriate and feasible pace. The reduction or elimination of these assets and the associated risks was a major contributing factor when developing the investment plans outlined in Section E of the DSP. For more information on Toronto Hydro's legacy assets, please refer to Section D2.

D3.2.2 Overview of Risk Mitigation Methods

Through its capital and maintenance investment plans, Toronto Hydro mitigates both the quantitative and qualitative risks identified above. Toronto Hydro manages risks by prudently investing in its assets while deriving value for customers. As such, the risk-based models and

Toronto Hydro-Electric System Limited
EB-2018-0165
Technical Conference
Schedule JTC3.21
Appendix A
FILED: March 29, 2019
(19 pages)

TORONTO HYDRO

INTERNAL AUDIT REPORT

Maintenance and Stations Capital

18-02-MSC

Prepared For	**Title**
Dino Priore	EVP & Chief Engineering and Construction Officer
Ben La Pianta	EVP & Chief Customer Care, EO&P Officer

For Information Purposes

Elias Lyberogiannis	GM, Engineering
John Borowitz	GM, Power System Services
Jim Trgachef	GM, Construction
Ashley Collier	Director, Enterprise Project Management and Development
Steve Strugar	Director, Distribution Stations
Anthony Haines	President & Chief Executive Officer
Aida Cipolla	EVP & Chief Financial Officer
KPMG	External Auditor

Date

2018-10-31

Assessment Period

January 2016 – December 2017

Audit Team

Scott Kiser	Director, Internal Audit
Rob Okashimo	Director, Corporate Risk & Disaster Planning
Githu Mundenchira	Internal Audit Consultant
Tahir Khuwaja	Internal Audit Consultant

Table of Contents

Audit Report Snapshot

Overall Rating
NEEDS IMPROVEMENT

Audit Report Ratings

Satisfactory	The area was found to have a robust control environment with finding(s) that would not likely create a significant negative impact for Toronto Hydro.
Needs Improvement	The area was found to have adequate controls except in certain specified areas and these weaknesses could potentially cause a significant negative impact for Toronto Hydro.
Needs Immediate Attention	The issue(s) found individually or in combination represent an unacceptable level of business risk that is virtually certain to have a significant negative impact on the operations of Toronto Hydro.

Issues

Impact/Severity	# Audit Issues
High	0
Medium	3
Low	3
Total Issues	6

Executive Sponsors
Aida Cipolla

Assessment Period
January 2016 to December 2017

Executive Summary

Background

The audit of Maintenance (All RC's) and Stations Capital processes (the "audit") was identified as a higher risk area and was included in the 2018 Internal Audit Plan (the "Plan").

Maintenance processes are critical components to fulfill the vision of Toronto Hydro to continuously maximize customer and stakeholder satisfaction by being safe, reliable and environmentally responsible at optimal costs.

Capital projects at stations enable Toronto Hydro to optimize the useful life of the assets in operations.

Toronto Hydro has invested $59.5M (including $36M paid to Hydro One for capital expenditure on capacity increment) in capital projects related to stations life cycle management programs in 2017. This audit, however, only focused on Toronto Hydro led expenditures on capital projects on stations and did not review the payments to Hydro One. A total of $46M was spent on operating maintenance activities that represents 16% of total operating expenses for Toronto Hydro for 2017.

Conclusion

The teams involved in planning, execution and monitoring of maintenance activities and stations capital work are fulfilling their mandate to achieve the overall vision of Toronto Hydro regarding customer and stakeholders' satisfaction. There are, however, opportunities to improve processes around overall governance structure, monitoring and quality assurance of the documentation. As the timely completion of these activities is critical to Toronto Hydro's success, these findings could potentially have a negative impact.

The overall rating for the Maintenance and Stations Capital audit is Needs Improvement. There are a total of six issues found during the audit, three are medium risk and three are considered low risk. These issues are summarized on the next page.

Summary of Observations

#	Observation	Process	Risk	Exposure
1	Lack of a Single Formal Maintenance Policy and Strategy	Maintenance	L	Although policies and strategies are contained in various documents, the absence of a single formal document may lead to inconsistencies in a clear vision and governance structure for maintenance activities within Toronto Hydro. It may also lead to potential conflicts of interpretation with respect to prioritization of maintenance activities especially corrective and reactive work.
2	Lack of formally documented Planned/Preventive Maintenance Process	Maintenance	L	Absence of a formally documented planned / preventative maintenance process flow may potentially lead to lack of clarity of roles and responsibilities of various RCs involved in the process especially at the points where responsibilities are handed over during the process.
3	Delays in attainment of "P1" Level Work Orders	Maintenance	M	• Delay in addressing high priority P1 work orders may have the potential to result in incidents. • Such incidents may cost Toronto Hydro more than the maintenance activity originally planned to mitigate the issue. • May potentially cause disruptions to the capital program of Toronto Hydro. • May potentially result in outages to customers.
4	Inconsistent Documentation of work performed in Red Construction Folders (RCFs)	Maintenance	L	• Incomplete evidence of the extent of work performed. • High risk issues may not be addressed / resolved properly. • May potentially result in incidents if the work was not performed as required.
5	Construction Drawings in finalized Green Construction Folders (GCFs) missing appropriate approvals.	Stations Capital	M	• Drawings without documented review may potentially have errors. • Risk of failed ESA Audit.

#	Observation	Process	Risk	Exposure
6	Delay in records updates from time of GCF completion	Stations Capital	M	• Missed updates may result in assets being missed from capital or maintenance planning cycle. • Efficiency/Safety concern from system missing assets.

Audit Objectives and Scope

The scope of this audit included two primary components:

- All TH maintenance processes; and
- TH-led Stations Capital processes.

The objectives of the audit were to evaluate the design and operating effectiveness of key controls in the Maintenance (all RC's) and Stations Capital processes to ensure:

1. All distribution assets were adequately maintained to sustain reliability of the system and optimize asset life. This included planning, execution, reporting deficiencies and trend analysis of maintenance activities and Short Interval Controls;
2. Compliance and adherence to the relevant provisions of Ontario Energy Board's (OEB) Distribution System Code and formally documented process maps and policies of Toronto Hydro applicable to Maintenance and Stations Capital processes;
3. Compliance and adherence to the metrics set by Toronto Hydro management to measure against the targets set within Custom Incentive Rate-setting (CIR) related to Maintenance and Stations Capital expenditures; and
4. Appropriate oversight of stations capital projects and maintenance processes to ensure that the projects are completed on time, on budget, in compliance with quality standards and are accounted for appropriately.

The audit engagement followed a risk-based approach where Internal Audit will document key operating procedures with a view to understanding how the stations capital projects plan and maintenance plan is established and monitored ensuring compliance with relevant rules and regulations.

Conclusion

The teams involved in planning, execution and monitoring of maintenance activities and stations capital work are fulfilling their mandate to achieve the overall vision of Toronto Hydro regarding customer and stakeholders' satisfaction. There are, however, opportunities to improve processes around overall governance structure, monitoring and quality assurance of the documentation. As the timely completion of these activities is critical to Toronto Hydro's success, these findings could potentially have a negative impact.

The overall rating for the Maintenance and Stations Capital audit is Needs Improvement. There are a total of six issues found during the audit, three are medium risk and three are considered low risk. These issues are detailed in the following pages.

It should be noted that new processes in the Stations Capital area have been developed and are in the process of being implemented. Once implemented they will rectify some of these issues. Besides that the new ERP implementation has created some revised processes which will also potentially rectify some of these issues.

3. **Delays in attainment of "P1" Level Work Orders**	
Risk	Medium
Process	Maintenance
Observation (18-02-MSC-03)	Internal Audit analyzed the data for the corrective / reactive work requests and work orders created and completed during the years 2016 and 2017. The analysis highlighted delays in attainment of work orders with assigned priority level of "P1". As per current practice, all work orders with assigned priority level of "P1" are suggested to be attained within 15 days. Only 27% of the work orders with assigned priority level of "P1" were attained within the suggested timeline of 15 days. The average attainment time of remaining 73% of "P1" work orders was 100 days. Although the RCs receive monthly reports for their outstanding work orders along with various other monthly reports and details are reviewed at bi-weekly or monthly team meetings, there is a lack of formal monitoring or accountability measures specific to high priority "P1" work orders.
Exposure	- Delay in addressing high priority P1 work orders may have the potential to result in incidents. - Such incidents may cost Toronto Hydro more than the maintenance activity originally planned to mitigate the issue. - May potentially cause disruptions to the capital program of Toronto Hydro. - May potentially result in outages to customers.

Management Response and Action Plan	*Management Response* The current reactive and corrective deficiency closure process (P1/P2/P3) tracks permanent closure of the identified deficiency which is usually through asset repair or replacement. However, the existing measures and process do not capture efforts to assess the deficiency and have interim mitigation of the risk within the targeted time periods. Evaluating system risk strictly on overdue P1s could give an incomplete view on the outstanding risks as it does not capture the severity of the unmitigated risks in the outstanding deficiencies. An example is in some cases a deficiency could be issued and an interim fix could be put in place as a risk mitigation approach if the asset cannot be repaired/replaced quickly. The P1 deficiency would remain open until the asset is repaired/replaced even though the risk may have been assessed and mitigated within the targeted time period. *Action Plan* a) Update language in current process documentation as "target" timeframes for P1/P2/P3 (completed). b) Develop and document process changes to: i. Reprioritize P1s if site-assessment and/or risk mitigation approaches deem the work is not required immediately, ii. Identify and improve the root causes of P1 latency so that P1 work can be completed within targeted time periods, iii. Identify if alternative/additional measures are needed to give visibility to risk exposure from overdue P1 work beyond the current attainment measures (31-May-19). c) Enterprise Program Management and Development (EPMD) has existing monitoring for Level 4 latency (P1, P2, P3) on the department dashboard. As mentioned in the observations, there are also work issuance reports to the operations business unit leaders showing the outstanding work and the date work was issued. To increase visibility around latency: i. MPP P1 Latency Reporting: Additional new content has been added to the monthly operations report for MPP meetings for P1s (completed). ii. Business Unit P1 Latency Reporting: Improve reporting / visibility of data to RC leaders on P1s to enhance visibility to P1 work and latency (31-Jan-19). d) Confirm RCF closeout process in SAP to determine potential for latency improvements from electronic closeout versus current methods (31-Jan-19).		
Designated Responsible Person(s)	Ashley Collier, Director, Enterprise Project Management & Development		
Executive Sponsors	Dino Priore, EVP and Chief Engineering & Construction Officer	Due Date	Q2 2019

System Service investments are forecast to increase from 2020 to 2022 and then return to a 2020 spending level in 2023 and 2024. This reflects the pattern of spending in the Energy Storage Systems and Station Expansions programs, while System Enhancements expenditures are forecast to remain relatively stable and Network Condition Monitoring and Control expenditures to steadily increase from 2020 to 2024.

A number of System Service programs included in the 2015-2019 plan are expected to be largely or entirely complete before 2020-2024, including:

- **Design Enhancements:** Moving forward, to improve planning and execution efficiency, Toronto Hydro will include design enhancements such as tree-proof conductor upgrades in planned System Renewal programs or in the Worst Performing Feeder segment (E6.7) for the 2020-2024 period.
- **Overhead Momentary Reduction:** Toronto Hydro is conducting a pilot for Overhead Momentary Reduction study for this program during the 2015-2019 period. It involves the installation of reclosers and communication infrastructure to minimize momentary interruptions to customers. Toronto Hydro plans to install four reclosers on the system in 2019. Toronto Hydro will assess technical issues of implementation such as relay coordination as well as practical benefits to reliability prior to determining the feasibility and benefits of this program.
- **Handwell Upgrades**: Toronto Hydro's replacement of deteriorated and high-risk handwells is on track for completion in the 2015-2019 period. This program involved replacing legacy handwells with non-conductive material as well as renewing the secondary cables between handwells. Due to the safety issue related to the legacy handwell units, Toronto Hydro has upgraded all known locations to the non-conductive type handwells. These upgrades addressed safety issues associated with the risk of contact voltage from conductive handwells so that the risk to individuals, pets, and wildlife are minimized.
- **Polymer SMD-20 Switch Renewal**: Replacement of defective SMD-20 switches is on track for completion during the 2015-2019 period. This program replaces all identified polymer SMD-20 switches in the system with a newer fiberglass core model. Due to the safety risks associated with operating the switch, all locations will be replaced by 2019.
- **Downtown Contingency**: In 2015-2019, this program was planned to address station level contingency risk through the establishment of inter-station feeder ties. Toronto Hydro successfully completed a number of overheard feeder ties, but upon re-evaluating the costs

RESPONSES TO ASSOCIATION OF MAJOR POWER CONSUMERS IN ONTARIO INTERROGATORIES

INTERROGATORY 22:
Reference(s): Exhibit 2B, Section A6, p. 33, Table 7

a) Please provide the percentage of capital that is undertaken by external contractors for each of the years 2015 to 2018 and forecast for 2019 to 2024.

b) Please provide the percentage of planned capital budget compared to reactive capital budget for each of the years 2015 to 2018 and forecast for 2019 to 2024.

c) Please provide the percentage of planned capital work executed as planned for each of the years 2015 to 2018.

RESPONSE:

a) Please refer to Toronto Hydro's response to interrogatory 4A-AMPCO-93 (b).

b) Please see to Table 1 below which contains 2015-2017 actual and 2018-2024 forecasted percentages of planned capital and reactive capital, respectively, as compared to total capital as presented in Appendix 2-AA.

Planned Capital is based on total capital in Appendix 2-AA (labeled as 'subtotal'), but excludes demand based projects related to Customer Connections and Externally Initiated Plant Relocations & Expansion, and excludes Reactive and Corrective Capital. The percentage of reactive capital included in the table below is based on the Reactive and Corrective Capital program as shown in Appendix 2-AA over total capital in Appendix 2-AA (labeled as 'subtotal'). Note that 2018 actuals are not available at this time.

Table 1: Percentage of Planned and Reactive Capital versus Total Capital Expenditures (2015-2024)

	Historical			Bridge		Forecast				
	2015	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Planned CapEx	84.5%	81.1%	83.9%	75.3%	76.3%	77.7%	78.2%	80.8%	79.7%	79.7%
Reactive CapEx	8.5%	10.6%	11.1%	13.0%	13.1%	11.8%	10.7%	10.8%	11.4%	11.5%

c) Please refer to Table 2 which includes the percentage of planned capital work executed as planned for each of the years from 2015 to 2018. Note that 2018 actuals are not available at this time. Also note that these results do not take into consideration demand-driven projects. Please see response to part (b) for the definition of projects considered Planned Capital.

Table 2: Percentage of Planned and Reactive Capital versus Total Capital Expenditures (2015-2018) ($ Millions)

	2015		2016		2017		2018	
	Plan	**Actual**	**Plan**	**Actual**	**Plan**	**Actual**	**Plan**	**Actual**
Planned Capital	455.9	415.5	426.5	414.7	361.3	417.9	401.9	n/a
Total Capital	**531.1**	**491.4**	**518.8**	**511.6**	**467.4**	**497.8**	**502.2**	**n/a**
% Planned CapEx executed as planned	**91%**		**97%**		**116%**		**n/a**	

Toronto Hydro-Electric System Limited
EB-2018-0165
Interrogatory Responses
2B-SEC-44
Appendix X
FILED: January 21, 2019
(49 pages)

technology

REPORT

A Review of Toronto Hydro's Newly Developed Asset Health Models

Professional Engineers Ontario

Temporary Licensee
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Limitations: Review of Toronto Hydro Electric Systems Limited Asset Condition Assessment methodology at their plant in Toronto, Ontario.

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1. Introduction

Toronto Hydro Electric System Limited (THESL), a wholly owned subsidiary of Toronto Hydro Corporation, owns and operates the electricity system that delivers electricity to approximately 761,000 customers located in Toronto. It is the largest municipal electricity company in Canada, and distributes around 19% of the electricity consumed in the province of Ontario.

THESL's distribution network comprises over 13,000km of underground cables and 15,000km of overhead lines which delivered 25,373GWh of electrical energy around the state of Ontario in 2016. THESL has been recognised by the Canadian Electricity Association as a sustainable electricity company in recognition of the THESL's commitment to providing electricity to customers in a way that minimises financial and environmental risks while maximising the benefit to society.

As part of its on-going commitment to progress towards excellence in sustainability, THESL is focussed on continuously improving its Asset Management practices. As part of this commitment, THESL has commenced the implementation of asset health models based on the Common Network Asset Indices Methodology (CNAIM). The Common Methodology, as it is often referred to, is the approach used by Distribution Network Operators (DNOs) in Great Britain to report asset health and criticality as part of their regulatory reporting requirements. THESL's intention is to use the outputs from their CNAIM-based models to support an advanced condition-based approach for planning and evaluating strategic capital investments and day to day maintenance activities.

EA Technology has supported the GB Distribution Network Operators through the development of the Common Network Asset Indices Methodology. Following the successful approval of CNAIM, we have worked with each of the DNOs to implement the methodology and embed it within their organisations.

Whilst the structure of the Common Methodology is publicly available, there is very limited experience of applying the Common Methodology outside Great Britain. In recognition of this, THESL have commissioned EA Technology to review their progress made to date, and to provide assistance as the methodology is rolled out to all assets.

This report presents the findings of our review into the progress made to date by THESL. The report is structured as follows:

- Section 2 presents the scope, objectives and approach to the project.
- Section 3 provides a brief overview of the Common Methodology.
- Section 4 provides a review of the structure of the models, the data used and the implementation of the CNAIM methodology.
- Section 5 summarises THESL's approach to quantifying asset criticality.
- Sections 6, 7 and 8 summarise THESL's approach to calibration of the models, how the outputs have been validated and now the models will be used within business-as-usual.
- Section 9 discusses the observations from THESL's implementation of CNAIM.
- Section 10 summarises the conclusions and recommendations from the Stage 1 of the project.

Abbreviations and acronyms used in the report are listed and defined in Appendix I.

Draft version 1.0 of this report was issued to Toronto Hydro on 4 September 2017. THESL provided feedback in the form of a marked-up copy on 13 September 2017. The feedback and clarifications have been incorporated into this final version 2.0 of the report, mainly in the form of footnotes to the existing text. In addition, Appendices II, II and IV have been added which provide a high-level review of THESL's substation power transformer, 4kV oil circuit breaker and wood pole models respectively.

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2. Scope and Objectives

2.1 Scope of Project

THESL have expressed a desire to enhance their in-house asset management capability by implementing a new asset health model to replace their existing Asset Condition Assessment (ACA) methodology. This is driven by a desire to put in place an asset health methodology that reflects the actual condition of the electrical network and can be used to inform the development of a condition based strategic investment programme and day to day maintenance activities.

THESL have appointed EA Technology to review the progress made in developing their new asset condition assessment tool. The project encompasses:

- reviewing the current processes and practices being employed by THESL to assess the extent to which they align with the principles and philosophy of CNAIM;
- where appropriate, to provide specific recommendations if it is considered that improvements can be made; and
- provision of on-going support to THESL's implementation team as the new CNAIM-based methodology is rolled out across the asset population.

In order to review the progress made by THESL, it has been agreed that EA Technology will review the following two asset class models in detail to assess the extent to which THESL's approach aligns with CNAIM:

- Submersible Transformers; and
- Overhead 3-Phase Gang Operated Switches (Manual).

2.2 Objective of Project

The overall project comprises four stages as highlighted below:

- Stage 1 – Review the two newly developed asset health models in detail and provide a more high-level review of the data inputs and calibration values for a further three models*
- Stage 2 – Common Methodology and asset condition modelling training
- Stage 3 – On-going support during modelling programme roll-out
- Stage 4 – Assistance with regulatory submission

This report presents our findings for Stage 1 of the project, which comprises the following tasks:

(1) review the newly developed asset health models, and associated documentation;

(2) review the approach to quantification for determination of asset criticality;

(3) review THESL's approach to model calibration;

(4) review the approach to validation of model outputs;

(5) determine how the asset health models will be used within business-as-usual (BAU);

(6) identify any areas for improvement and make recommendations; and

(7) document the findings from tasks 1-6 in a report.

* Following the completion of the detailed model reviews, it was agreed that a high-level review of the substation power transformer, 4kV oil circuit breaker and wood pole models would be undertaken (see Appendices II, III and IV).

2.3 Approach

When the project was commissioned, it was intended to carry out Stage 1 through a combination of off-site and on-site working, including a series of workshops covering tasks 1 to 5 (see Section 2.2 above) during a single visit to THESL's offices. However, issues with the process for visa and licence applications for business purposes within the province of Ontario have resulted in an unforeseen delay in EA Technology personnel being granted the appropriate permissions to work in Canada. Therefore, the review has been undertaken from the UK using the following documents provided by THESL:

- Submersible Transformers Operating Context.pdf
- Submersible Transformers Model Output_V1.xlsx
- Inspection form – Submersible Transformers.xlsx
- Overhead Gang Operated Switches Operating Context.pdf
- Overhead Gang Operated Switches Model Output_V1.xlsx
- Inspection Form – 3 Phase Overhead Gang Operated Switches.xlsx

The content of these documents and THESL's approach to tasks 1 to 5 have been explored via a series of teleconference and Webex meetings held on the following dates:

- Tuesday 18 July 2017
- Thursday 27 July 2017
- Thursday 3 August 2017
- Tuesday 8 August 2017
- Thursday 10 August 2017

In addition, a teleconference/Webex meeting was held on Friday 11 August 2017 to outline the findings from the Stage 1 review and to discuss the recommendations and suggested training requirements for Stage 2.

3. The Common Methodology

Within Great Britain, Distribution Network Operators are regulated by Ofgem, a government appointed regulator. Ofgem use an economic approach to regulation by agreeing a suite of performance based targets and operating licence contractual terms with DNOs over a series of "Price Control Periods". These targets range from metrics which reflect customer experience, overall network performance through to capital and revenue allowances.

The GB energy regulator Ofgem introduced regulatory reporting requirements for GB Distribution Network Operators for the regulatory period running from 2015 to 2023 (referred to as RIIO-ED1). RIIO (Revenue = Incentives + Innovation + Outputs) marks a significant shift away from the previous RPI-X regulatory approach aiming to reduce costs within the utility sector to a more outcome-based regulatory reward system.

In order to facilitate these changes, a number of modifications to the requirements placed on network operators via their operating licences have been introduced. These include the requirement for DNOs to jointly develop a common framework referred to as the Common Network Asset Indices Methodology (CNAIM or the Common Methodology), such that DNOs adopt a common approach to the evaluation of asset health and criticality. DNOs are now required to report information on asset health and criticality using this Common Methodology. This enables Ofgem to be able to make direct comparisons between each of the GB licence holders.

The Common Network Asset Indices Methodology covers 25 electrical assets classes including Switchgear, Transformers, Overhead lines and Cables.

Most of the GB DNOs already had Condition Based Risk Management (CBRM) decision support tools developed in conjunction with EA Technology. Thus, CBRM was the logical starting point for the network operators' working group in developing a new common reporting standard and EA Technology was invited to assist in the development of the DNO Common Network Asset Indices Methodology[*] (CNAIM). An overview of the process that has been developed is shown in Figure 1.

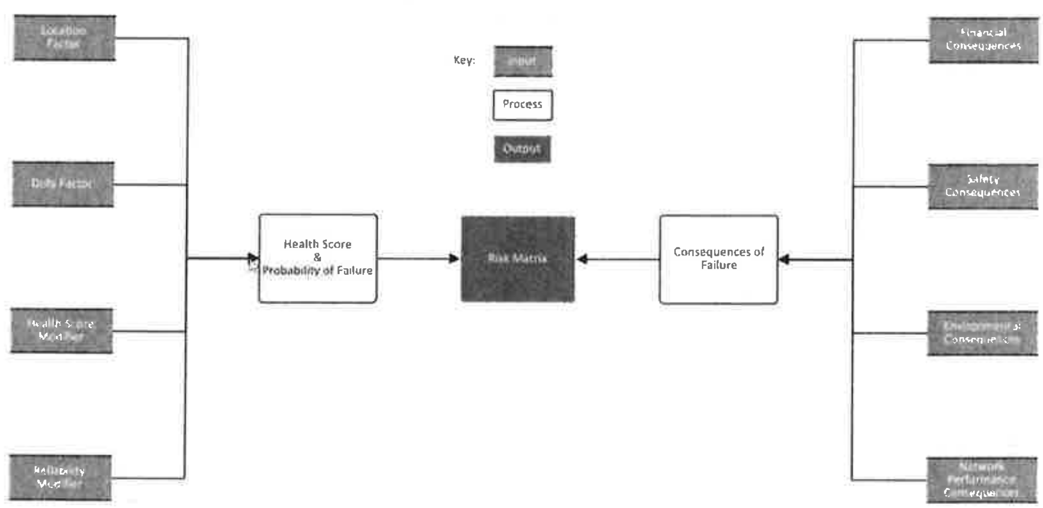

Figure 1 Overview of Common Network Asset Indices Methodology

The Health Score provides a measure of the condition of an asset and the proximity to the end of its useful life. This includes the current health which is informed by observed and measured

[*] DNO Common Network Asset Indices Methodology Version 1.1, Ofgem, 30/01/2017: https://www.ofgem.gov.uk/system/files/docs/2017/05/dno_common_network_asset_indices_methodology_v1.1.pdf

condition factors as well as the future health based on assumptions on the likely future deterioration. The methodology includes age based elements and provides a continuous scale for the assessment of asset health. The methodology also specifies the exact relationship between the Health Score of an asset and its probability of failure.

In addition, the methodology includes a common approach for the evaluation of the likely consequences of failure associated with condition based failures, expressed in monetised values. The criticality of each asset is then determined by comparing the consequences of failure for that asset with the average for the population.

The information is used for the regulatory reporting of the following three components:

- Health Index which relates to asset health and probability of failure;
- Criticality Index which relates to the consequences of failure; and
- Risk Index which is a monetised risk measure determined from the combination of the Health Index and Criticality Index.

Only the first element of CNAIM (i.e. the derivation of a Health Index) is considered here.

Under the Common Methodology, the current health of an asset is represented by a Health Score (the Current Health Score) using a continuous scale between 0.5 and 10, where 0.5 represents an asset in the same condition as would be expected when new. A Health Score of 5.5 represents the point in an asset's life beyond which significant deterioration may begin to be observed. This is where the probability of failure of the asset is approximately double that of a new asset. A Health Score of 10 represents an asset in extremely poor condition, where the probability of failure is 10 times that of a new asset.

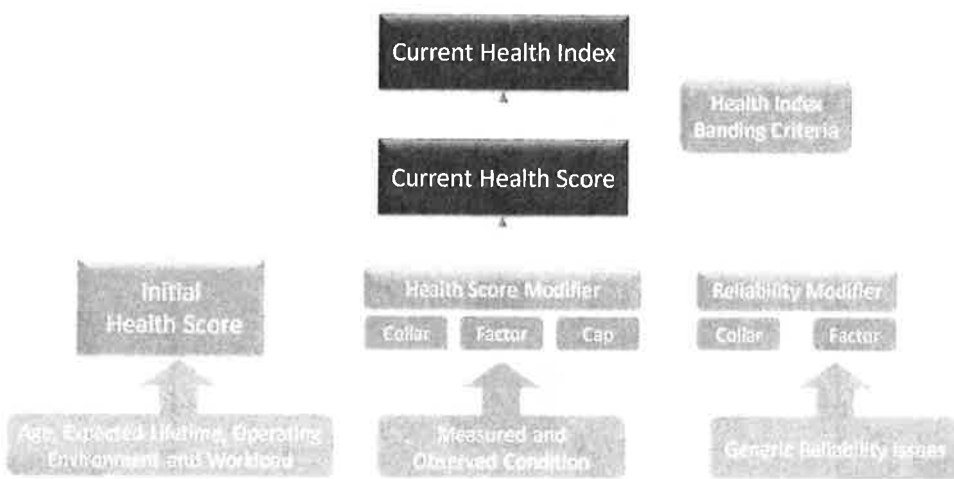

Figure 2 Derivation of Current Health Index

The detail of the CNAIM health index formulation is depicted in Figure 2 and can be summarised as follows:

(1) An Initial Health Score is calculated using knowledge and experience of the asset's performance and expected lifetime, taking account of factors such as manufacturer, operational experience and operating conditions (duty, proximity to coast, etc.).

(2) The Initial Health Score is then adjusted by the Health Index Modifier, which is based on the known condition of the asset. It includes condition that is gathered by inspecting the asset, together with any condition information obtained through diagnostic tests, measurements or functional checks. The observed and measured condition inputs are used to derive a Health Score Factor, Health Score Cap and a Health Score Collar.

(3) A Reliability Modifier can also be applied to modify the Current Health Score to reflect generic issues affecting asset health and/or reliability associated with a specific manufacturer or model type. The Reliability Modifier comprises a Reliability Factor and a Reliability Collar.

(4) The Current Health Score is then derived by adjusting the Initial Health Score by the Health Score Factor and the Reliability Factor, subject to upper and lower thresholds defined by the Health Score Collar, the Reliability Collar and the Health Score Cap.

(5) For the purposes of regulatory reporting, the Current Health Score is mapped onto one of five Health Index (HI) bands using the criteria in Table 1.

Table 1 Health Index Banding Criteria

	Health Index Banding Criteria	
Health Index Band	**Lower Limit of Health Score**	**Upper Limit of Health Score**
HI1	≥0.5	<4
HI2	≥4	<5.5
HI3	≥5.5	<6.5
HI4	≥6.5	<8
HI5	≥8	≤15

As stated in Section 4.2.4, the way in which condition collars have been applied means that it is unlikely that the health index profile depicted in Figure 3 is a true reflection of the asset health (and therefore remnant life) of the population of overhead gang operated switches. This is discussed further in Section 6.

4.3 Summary

Toronto Hydro's implementation of CNAIM to derive a Current Health Score and an associated Health Index is in line with the approach outlined in the Common Network Asset Indices Methodology document. Good use has been made of the available inspection data to produce a number of observed and measured condition inputs for the two models. The mapping and combination of the data inputs is logical and transparent.

A general observation on the model outputs provided by THESL is that there is no means of identifying individual assets other than the unique equipment number. It is suggested that additional information fields are included in the models to enable assets to be more easily identified; examples include site/location of the asset and manufacturer/model/type. Inclusion of such information is particularly useful during calibration sessions as it will allow more detailed interrogation/filtering of the model outputs.

A few minor anomalies have been identified; these were highlighted in the sections above and are summarised below[1]:

- The application of the MMI technique to calculate the Measured Condition Factor in the submersible transformer model does not appear to be working correctly where the Temperature Readings Factor is greater than 1.
- The values used for the Temperature Readings Collar in the submersible transformer model do not correspond to those stated in the *Toronto Hydro Health Index Model* description document provided by THESL.
- The values and descriptions used for the Circuit Interruption Modifier, Switch Condition Modifier and Connections Condition Modifier in the overhead gang operated switch model do not correspond to those stated in the *Toronto Hydro Health Index Model* description document provided by THESL.

THESL's models appear to contain a subset of the population of submersible transformers and overhead 3-phase gang operated switches[2]. It is recommended that THESL include the entire asset population within the models, irrespective of how little data currently exists. This will provide visibility of where additional asset information should be collected in order to gain a better understanding of the current health of the entire asset population. Where manufacturing/ commissioning dates are not available, EA Technology can provide guidance on ways to estimate indicative dates such that a health score can be derived.

At present, the health index is derived purely from the condition inputs; i.e. the same average lives have been applied throughout each model and the Location Factor and Duty Factor are defaulted to unity. Going forwards, THESL may wish to consider enhancing the health index derivation as outlined in the sections above:

- The expected service life of assets could be split by, for example, manufacturer/model type, asset design or operating voltage.
- Environmental influences that are relevant in Ontario and affect the service life of assets could be incorporated into the Location Factor. One example highlighted during this review is to identify sites that are prone to flooding for inclusion in the submersible transformer model.

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[1] Following the delivery of draft v1.0 of this report it is understood that THESL have addressed all of the minor anomalies.

[2] It is understood that the entire population for both asset classes have been included in their respective models.

- Inclusion of data to drive the Reliability Modifier. For example, the Reliability Modifier could be used to capture information on Suspension of Operational Practice / Operational Restrictions.

The inclusion of such refinements will increase the accuracy of the health index derivation and will allow more differentiation between assets. This is useful when determining the ageing rate of the assets, their performance (probability of failure), the level of risk associated with different assets and, ultimately, determining the optimum intervention programme based on risk.

Consideration could also be given to separating some of the condition inputs into additional modifiers; for example, in the submersible transformer model, corrosion issues and oil leakage issues could be treated as two observed condition modifiers rather than combining them to a single External Condition of Tank Modifier. This may ease the burden of the data mapping / combination element of THESL's rollout of the remaining models.

The key issue that has been identified during the review of the models is the way in which condition collars have been applied. This is likely to be distorting the results and, if the results are rolled forwards, will give a particularly pessimistic view of the future health index profile of the asset portfolio. This is discussed further in Section 6.

10. Conclusions and Recommendations

EA Technology believe that THESL have correctly identified the appropriate combination of tactical and strategic methodologies in order to develop their in-house asset management policies, practices and procedures. Although the scope of work upon which this review has been based is limited to consideration of the newly developed CNAIM-based models for determining a current health score, the project team has also considered some aspects of the RCM inspection regime where it has been deemed appropriate to do so.

EA Technology consider the combination of a CNAIM-style strategic investment model, supported by an effective RCM based inspection and corrective maintenance programme, as being good (if not best) practice for managing the asset base in question. When fully established, this combination will prove to be a very efficient and effective means of delivering a condition-driven, risk-based approach to asset investment.

Toronto Hydro's implementation of CNAIM to derive a Current Health Score and an associated Health Index is in line with the approach outlined in the Common Network Asset Indices Methodology document. THESL have chosen the most appropriate model structures, and appear to have made the best use of the inspection data currently available to produce a number of observed and measured condition inputs for the two models; the mapping and combination of the data inputs is logical and transparent. It is recommended that additional information fields are included in the models as this will make calibrations sessions easier and allows more detailed interrogation of the model outputs. A few minor anomalies have been identified and it is suggested that these should be investigated and rectified as appropriate[*].

THESL's models appear to contain a subset of the population of submersible transformers and overhead 3-phase gang operated switches. It is recommended that the entire asset population is included within the models, irrespective of how little data currently exists, as CNAIM-type models are designed to work with incomplete data sets[†]. In addition, it will provide visibility of where additional asset information should be collected in order to gain a better understanding of the current health of the entire asset population. Where manufacturing / commissioning dates are not available, EA Technology can provide guidance on ways to estimate indicative dates such that a health score can be derived.

The key issue that has been identified during the review of the models is the way in which condition collars have been applied. It is believed that this is distorting the results and, if the results are rolled forwards, will give a particularly pessimistic view of the future health index profile of the asset portfolio. The application of model calibrations that are directly linked to the routine inspection and tactical maintenance programme does not follow the principles and philosophy of CNAIM.

Based on the findings of Stage 1 of the project, EA Technology recommends that the following activities are completed before THESL rolls out any further CNAIM-based models:

- Undertake training to gain a more detailed understanding of CNAIM in the following areas:
  - The background, underlying philosophy and principles of the core methodology for the estimation of current asset health.
  - Principles and process of calibration. It is suggested that this training session should include the calibration of one or both of THESL's newly developed models that have been reviewed during Stage 1 of this project.
- THESL may wish to consider additional in-depth training to gain a better understanding of other elements of risk-based investment modelling; for example:

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[*] It is understood that THESL have addressed the anomalies following the delivery of draft v1.0 of this report.
[†] In THESL's feedback on draft version 1.0 of this report, they have indicated that the entire population of both asset classes have now been included in the respective models.

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- determination and re-calculation of the asset ageing rate (used for estimating future asset health);
- inclusion of different failure modes and the determination of the constants in the probability of failure equation;
- approach to determining the consequences of failure in the four categories of network performance, safety, financial and environmental;
- derivation of asset criticality and criticality index;
- modelling different investment scenarios for risk-based decision making.

This training will assist THESL in the extension of their CNAIM-based models to incorporate future health, probability of failure and estimation of asset risk.

- Separation of the inspection result categorisation process from the newly developed models such that they align with the principles and philosophy of CNAIM.

EA Technology also recommends that the following activities are undertaken in conjunction with the roll-out of further models:

- Inclusion of future health score. This requires only a few additional computational steps and is useful when calibrating the models as a check to how fast the assets are moving through the health index bands. In addition, the use of current and future health profiles will provide a more robust basis for determining future investment needs.
- Presentation of the results on a more granular scale than that used in CNAIM (i.e. more health index bands). This will give better visualisation of the movement of assets through their respective lifecycles.
- Consideration could be given to including a larger number of condition modifiers; i.e. treating condition inputs separately rather than combining them as in the submersible transformer and overhead gang operated switch models. This may not affect the accuracy of the results but could ease the burden of the data mapping / combination element of THESL's planned rollout of the remaining models over a short time period.

EA Technology suggests the following longer-term recommendations to improve the CNAIM-based models:

- Refinements to increase the accuracy of the health score derivation. Examples could include:
  - splitting the expected service life of assets by manufacturer/model type, asset design or operating voltage;
  - incorporation of environmental influences that affect the service life of assets in Ontario into the Location Factor; and
  - inclusion of data on known reliability issues or operational restrictions to drive the Reliability Modifier.

  The inclusion of such refinements will allow more differentiation between assets. This is useful when determining the ageing rate of the assets, their performance (probability of failure) and the level of risk associated with different assets.

- Further development in the area of asset criticality to consider all of the consequence categories included in CNAIM (i.e. network performance, safety, financial and environmental). This will enable THESL to compare the level of risk between asset classes on a consistent basis and, ultimately, to develop sustainable strategic investment plans.

in the station power transformer model and, likewise, THESL have used the same DGA divider value as specified in Common Methodology to calculate the DGA Test Collar.

For all five gases, the lowest condition state score is 2 compared with 0 in the CNAIM calibration settings. This has the effect of increasing the DGA Score for low levels of gases compared with the CNAIM calibration values and, as a result, the calculated DGA Test Collar values are higher than those obtained using the CNAIM condition state calibration values. In THESL's station power transformer model, over 60 assets have a Current Health Score that has been 'forced' by the DGA Test Collar compared with only 3 assets when the CNAIM DGA condition state settings are applied. The 'Condition 1' criterion represents a condition state whereby the transformer is operating satisfactorily, and it is suggested that a condition state score of 0 would be more appropriate than a condition state score of 2.

The DGA Test Factor is derived by comparing the most recent DGA Score with the previous DGA Score. THESL have applied the same percentage change bands and calibration settings as used in CNAIM. However, it has been noted that where no previous DGA test results exist, a change category of 'Large' is applied, corresponding to a DGA Test Factor of 1.4. It is suggested that where there is only one set of DGA test results, then the change category should default to 'Neutral' (i.e. a DGA Test Factor of 1).

The derivation of the DGA Test Modifier in Common Methodology takes no account of the time period between tests. A possible enhancement to THESL's station power transformer model would be to set the change category and / or DGA Test Factor depending on the length of time between test results.

FFA Test Modifier

THESL have adopted the same approach as documented in the Common Methodology; i.e. using the same calibration values and equation for calculating the FFA Test Collar.

Reliability Modifier

THESL have not included the Reliability Modifier in their station power transformer model. If any issues affecting particular groups of assets become apparent in the future, then the Reliability Modifier would be an appropriate place to capture and utilise this knowledge. However, it must be noted that the reliability input values directly impact the asset health score and, as such, their use must be justifiable.

Current Health Score

In CNAIM models, the Current Health Score of an individual asset is determined from its Initial Health Score adjusted by the Health Score Factor, subject to the upper and lower thresholds defined by the Health Score Cap, Health Score Collar and Reliability Collar. The Current Health Score in THESL's station power transformer model has been derived in the same way.

The Current Health Score is a measure of the remaining useful life of an asset. As already stated, the expected service life appears to be too low given the age of the substation power transformer population in the model and, hence, the model is probably underestimating their remaining useful lives. In addition, the Current Health Score of around 25 percent of the assets have been 'forced' by the DGA Test Collar which is likely to be presenting an overly pessimistic view of the remnant lives of this subset of assets.

Reliability Modifier

THESL have not included the Reliability Modifier in their 4kV oil circuit breaker model. If any issues affecting particular groups of assets become apparent in the future, then the Reliability Modifier would be an appropriate place to capture and utilise this knowledge. However, it must be noted that the reliability input values directly impact the asset health score and, as such, their use must be justifiable.

Current Health Score

In THESL's 4kV oil circuit breaker model, the Current Health Score of an individual asset is determined from its Initial Health Score adjusted by the Health Score Factor, subject to the upper and lower thresholds defined by the Health Score Cap and Health Score Collar. The derivation is the same as described in the Common Network Asset Indices Methodology document.

The Current Health Score is a measure of the remaining useful life of an asset. As already stated, the expected service life is too low given the age of the 4kV oil circuit breaker population in the model and, hence, the model is underestimating their remaining useful lives. The corresponding Health Index Profile shows almost 70 percent of the assets to be in HI3; this is primarily driven by the expected service life that has been used and is unlikely to be providing an accurate reflection of the asset health of the population of 4kV oil circuit breakers.

RESPONSES TO SCHOOL ENERGY COALITION INTERROGATORIES

INTERROGATORY 44:

Reference(s): Exhibit 2B, Section D, Appendix C

With respect to the 'Toronto Hydro Asset Condition Assessment Methodology':

a) Please explain how asset age is incorporated into the methodology.

b) Please explain how expected asset useful live is incorporated in the methodology.

c) Please provide a copy of the DNO Common Network Asset Indices Methodology [note: For the purposes of your response, it is acceptable to simply provide the document by way of a web link]

d) [p.8] Please provide a copies of all documents provided to Toronto Hydro by EA Technologies related to: i) the recommended areas of improvement, and ii) guidance and training documents.

e) [p.8] Did Toronto Hydro agree to all the recommended areas of improvement provided by EA Technologies? If not, please explain why not.

RESPONSE:

a) As explained on pages 7, 8 and 17 of Exhibit 2B, Section D, Appendix C, age is used to calculate the Initial Health Score of an asset. The Initial Health Score is calculated based on the asset's age and expected life, taking into account its operational use and

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operating conditions. The Current Health Score is determined by applying the observed or measured condition of the asset (i.e. the Health Score Modifier), as well as a Reliability Modifier, to the Initial Health Score.

b) As explained on pages 14 and 15 of Exhibit 2B, Section D, Appendix C, the Useful Life for an asset is used in combination with a duty factor and a load factor to calculate the Expected Life value for an asset. This value is then used to calculate the Initial Aging Rate, which is an input to the Initial Health Score discussed in part (a).

c) Link to the DNO Common Network Asset Indices Methodology: https://www.ofgem.gov.uk/system/files/docs/2017/05/dno_common_network_asset_indices_methodology_v1.1.pdf

d) Toronto Hydro is unable to provide training documents as training was carried out through a series of in person sessions. Guidance was provided through a series of conference calls as well as the documentation appended to this response listed below.

Documents provided to Toronto Hydro by EA Technology related to the recommended areas of improvement are attached to this response in Appendices A through Y, as listed below:

- Appendix A: Stage 1 Report - Asset Condition Assessment Project (September 2018)
- Appendix B: General Observations and Wider Concerns (January 2018)
- Appendix C: Review No. 21 - Air Insulated Submersible Vault Switches
- Appendix D: Review No. 20 - SF6 Insulated Submersible Vault Switches
- Appendix E: Review No. 19 - SF6 Pad Mounted Switches

- Appendix F: Review No. 18 - Air Blast Circuit Breakers
- Appendix G: Review No. 17 - Underground Vault
- Appendix H: Review No. 16 - Cable Chambers
- Appendix I: Review No. 15 - Pad Mounted Transformers
- Appendix J: Review No. 14 - Vacuum Circuit Breakers
- Appendix K: Review No. 13 - Air Magnetic Circuit Breakers
- Appendix L: Review No. 12 - Network Protectors
- Appendix M: Review No. 11 - Network Transformers
- Appendix N: Review No. 10 - Wood Poles
- Appendix O: Review No. 9 - SF6 Circuit Breakers
- Appendix P: Review No. 8 - Vault Transformers
- Appendix Q: Review No. 7 - SCADAMate R2 Switches
- Appendix R: Review No. 6 - Air Insulated Pad Mounted Switches
- Appendix S: Review No. 5 - KSO Oil Circuit Breakers
- Appendix T: Review No. 4 - 4 kV Oil Circuit Breakers
- Appendix U: Review No. 3 - 3 Phase Overhead Ganged Switches
- Appendix V: Review No. 2 - Station Power Transformers
- Appendix W: Review No. 1 - Submersible Transformers
- Appendix X: THESL Asset Condition Assessment Review (November 2017)
- Appendix Y: Email thread - New definitions for Health index buckets

e) For Appendices B through W, Toronto Hydro accepted EA Technology recommendations with specific exceptions. Please note that in all instances where recommended improvements were implemented or further discussed, EA Technology was in agreement with the modifications made to the models or accepted Toronto Hydro's reasoning for not making any changes. In certain instances where Toronto

Hydro was unable to make the changes, the utility intends to explore the improvements further as it continues to refine and improve the calibration of the model. As stated by EA Technology in their September 2018 final report in Appendix A, Toronto Hydro "made sensible and constructive local modifications to model input data streams, and on occasion have also sought to adjust model architecture to reflect the differences of asset ownership and operation between Great Britain and Canada. These variations, and therefore the models developed by THESL, are in the opinion of EA Technology, consistent with the underlying objectives and principles of the CNAIM methodology."

As part of two intermediate stage reports (Appendix X and Appendix B), in addition to individual model review documents, and the email thread attached as Appendix Y, EA Technology recommended areas of improvement that fall under the following themes:

- **Collars and Calibrations**: In the November 2017 report (Appendix X), EA Technology identifies concerns with the collars and calibrations used in Toronto Hydro's models and states that Toronto Hydro has set its collars for some asset classes to trigger operational activities. Through the iterative reviews of the models and discussions with EA Technology, Toronto Hydro refined and adjusted collar values for these asset classes while taking into consideration the utility's specific operating context. For the majority of the models and where suggestions and recommendations were incorporated to better reflect the asset condition, EA Technology found the adjustments to be in line with the underlying principles and objectives of the CNAIM methodology. With respect to Toronto Hydro's legacy 4 kV Oil, KSO Oil, and Air Blast Circuit Breaker models (Appendices T, S, and F, respectively), the parties did not come to a consensus. Toronto Hydro did not agree with EA Technology's recommendations to adjust the calibration values due to the specific nature of these legacy assets.

- **Inspection data:** In every Model Review document (Appendix C-W, i.e. No. 1 through No. 21), EA Technology recommended Toronto Hydro include additional types of inspection data that it does not currently collect. It should be noted that Toronto Hydro collects sufficient inspection data to rely on the results from the ACA methodology. However, Toronto Hydro also notes that the additional inspection data would likely enhance the accuracy of the results. As part of continuous improvement, Toronto Hydro updates its inspection forms and processes on a regular basis resulting in a more accurate picture of the condition of its assets.

- **Asset definition**: EA Technology highlighted concerns with how asset health is applied to certain assets with multiple significant sub-components. Specifically, switchgears are comprised of two separate components: a fixed portion (i.e. the bus bar, cable termination, and other switchgear elements) and a moving portion (i.e. the circuit breaker itself). EA Technology observed that Toronto Hydro only generates a health score for the moving portion (for example, refer to Appendix K, Air Blast Circuit Breakers). Where Toronto Hydro considers the fixed components to be part of the switchgear, EA Technology considers them to be a part of the circuit breakers. As noted in Toronto Hydro's response to interrogatory 2B-Staff-71, part (b), the utility does not currently have the data necessary to calculate a health score for the fixed portions of its switchgear. Furthermore, as noted in response to 2B-AMPCO-39, part (b), in addition to using Health Scores in decision-making, Toronto Hydro uses available maintenance records outside of the ACA algorithm to support tactical intervention and strategic investment planning. Adjustments and modifications integrated into the ACA models were made to suit Toronto Hydro's operating context. Ultimately, EA Technology found that the local variations made to the models are consistent with the underlying objectives and principles of the CNAIM methodology.

- **HI Banding Definition:** EA Technology recommended that HI2 definition be amended which Toronto Hydro agreed to. An earlier version of the HI2 band defined it as "Minor deterioration in serviceable condition, may require assessment" as seen in Appendix Y (i.e. email thread). EA Technology suggested Toronto Hydro re-visit the definition to amend the "may require assessment" statement to either "assessment is to be undertaken" or "it is not". Toronto Hydro amended the HI2 band definition to not require undertaking an assessment.

- **Calibration of Average Life**: EA Technology noted that Toronto Hydro's expected (i.e. useful) life values for certain asset classes (Air Magnetic, Cable Chambers, Padmount Transformer, Underground Vaults, Vacuum Circuit Breaker, Network Transformers, Vault Transformers, and Air Blast Circuit Breakers) were broadly set and recommended dividing the asset populations into sub-groups (e.g. manufacturer/model data, duty, and counter readings) and reviewing the useful life values associated with these components. (See Appendices K, H, I, G, J, M, P, and F, respectively.) The values used in Toronto Hydro's ACA methodology are aligned with 2009 Kinectrics report, "Toronto

Hydro-Electric System Useful Life of Assets".[1] Toronto Hydro intends to update its useful life values in the future, and will explore opportunities to consistently gather and incorporate more granular information such as manufacturer/model data where appropriate.

- **Calibration of Duty & Counter Readings, Maintaining ACA Model Quality (Data Granularity and Quality)**: EA Technology suggested adding more granular data on the condition of assets by identifying sub-groups (e.g. manufacturer/model data, duty, and counter readings) in the ACA methodology. Toronto Hydro notes that this information can enhance the ACA methodology. As discussed in Exhibit 2B, Section D, Appendix C, page 13, more data can be collected from field inspections and will be considered as part of ongoing improvements.

- **Location Calibration:** EA Technology recommended Toronto Hydro incorporate more details for the Location Factor in the ACA methodology. As discussed in Exhibit 2B, Section D, Appendix C, page 13, Toronto Hydro defaults Location Factor to 1.0 and is currently engaged in developing condition criteria that will account for the effects of Toronto's environment on the asset deterioration process.

- **Model Alignment:** EA Technology identified the risk of potential investment walls in future years for certain assets. EA Technology recommended regular reviews of the calibration values and, as noted in the points above, more granular asset data to be used as part of the ACA methodology. As part of

[1] Toronto Hydro has provided a copy of this report as Appendix A to its response to interrogatory 2B-SEC-38.

continuous improvement, Toronto Hydro updates its inspection forms and processes on a regular basis resulting in a more accurate picture of the condition of its assets. Toronto Hydro will continue to explore additional types of data to continuously improve the calibration and accuracy of its ACA models.

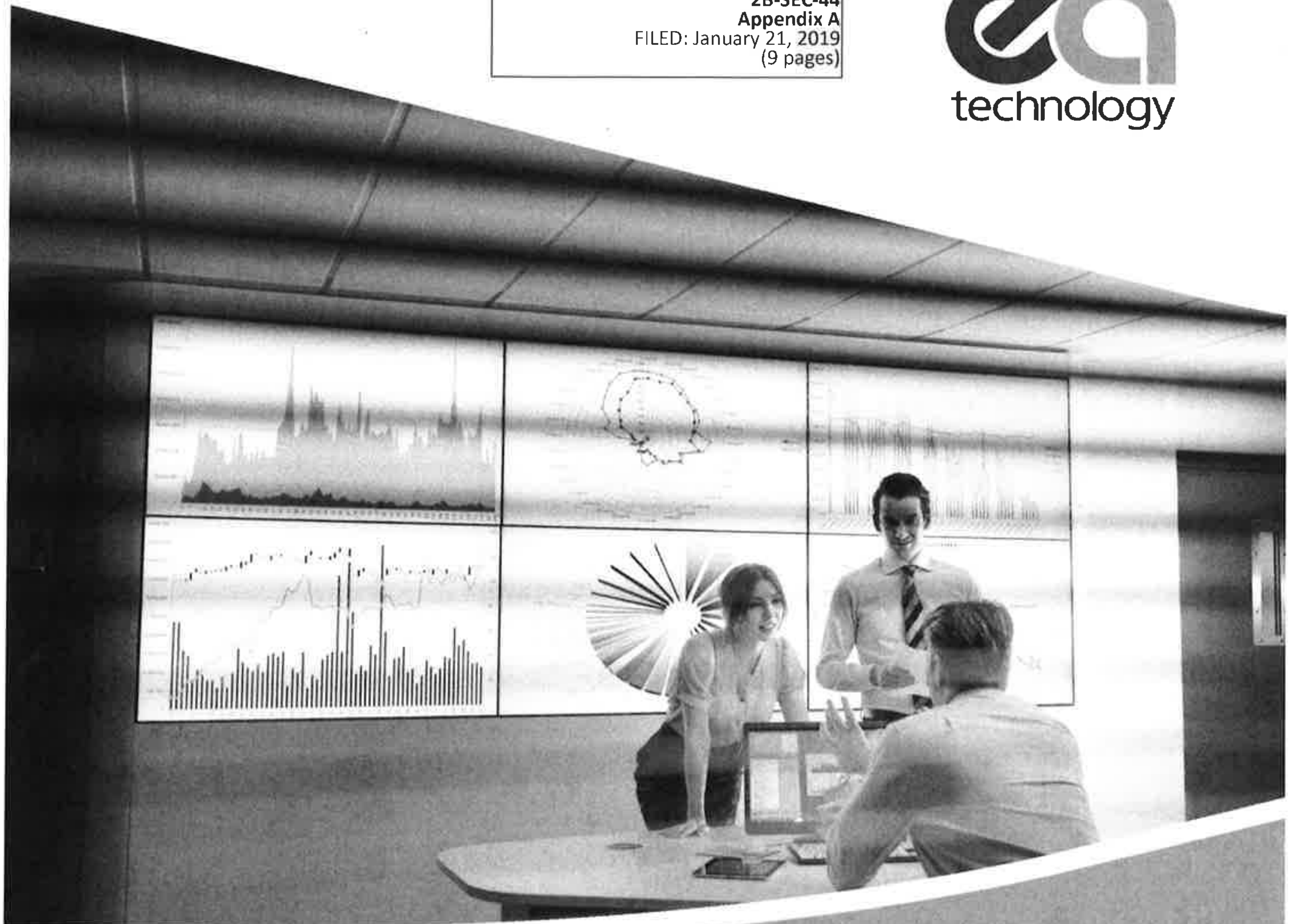
- **Condition Point Calibration and established Toronto Hydro practices:** As stated in Appendix J, EA Technology identified issues with how Toronto Hydro applied calibration scores for circuit breakers that are inspected and have deficiencies addressed at the same time in the field. As part of Toronto Hydro's maintenance work (Exhibit 4A, Tab 2, Schedule 1-4), when deficiencies are identified on station circuit breakers through inspections, Toronto Hydro attempts to repair the asset immediately as assets are already de-energized for inspection purposes. As such, in the asset condition models, Toronto Hydro does not a apply a calibration factor to increase the health score of the asset, but applies a reduced calibration score which results in lower health score (i.e. low health index band) as the deficiency was addressed at the time of inspection. After consulting with Toronto Hydro, EA Technology understood Toronto Hydro's circuit breaker maintenance practices (specifically, the 'Find It and Fix It' philosophy). As previously stated, EA Technology supported that the variations were found to be in line with the objectives and principles of the CNAIM methodology.

As noted in the themes described above, Toronto Hydro plans to further refine and continuously test the methodology and its calibrations by validating the results against field data (i.e. inspections). Increased maturity will be achieved by exploring additional types of data to continuously improve the calibration and accuracy of the results, developing condition criteria to account for the effects of Toronto's environment on the asset deterioration process. Toronto Hydro also plans to consistently gather and incorporate more granular information such as manufacturer/model data where appropriate.

EA Technology considers continuous improvement to be the natural progression of models, as stated in their final report (see Appendix A): "We would expect that following a period in which the new ACA methodology "beds-in" (matures) within the organisation, existing asset inspection, maintenance, operational, and investment policies and procedures may be revised in order to capture more asset specific data and new opportunities to further improve over time as the benefits of this approach are realised. EA Technology consider this to be a natural process in which models will incrementally improve over time as the benefits of this approach are realised."

Toronto Hydro-Electric System Limited
EB-2018-0165
Interrogatory Responses
2B-SEC-44
Appendix A
FILED: January 21, 2019
(9 pages)

technology



REPORT

Stage 1 Report - Asset Condition Assessment Project

Prepared for: Toronto Hydro Electric System Ltd

Project No: 116410
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10-Aug-2018	Draft	A. Harrison & T. Pears	For review by THESL
06-Sep-2018	V1	A. Harrison & T. Pears	Revision following THESL review

Final Approval

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Contents

1. Who is EA Technology ?

EA Technology originated in 1966 as the UK Electricity Council's Research Centre (ECRC). Effectively a grant funded entity, ECRC's role was to investigate new ways for people to use electricity and better ways for it to be distributed to customers. When the UK electricity industry was privatised in 1990, EA Technology 'spun out' of national ownership to become an independent organisation. The funding from the network operators and energy suppliers was progressively ramped-down and EA Technology made the transition to a commercial entity. In 2004 we became an employee-owned, innovation-focussed organisation. Our headquarters are in Capenhurst in the Northwest of England and we have around 200 employees with offices in North America, Australia, Singapore, China and the Middle East.

Our customers include electricity generation, transmission and distribution companies, together with major power plant owners and operators in the private and public sectors. We are committed to providing our customers with innovative products and services, consultancy and training which deliver tangible benefits for their businesses enabling them to create safer, stronger and smarter networks for today and the future.

As a world-renowned provider of consultancy and technical services to the electricity industry, EA Technology has been intimately involved and at the cutting edge of technical, business, legislative and regulatory developments for 50 years. We have worked with over 60 utilities worldwide to improve their asset management capabilities, developing asset management strategies, implementing Condition Based Risk Management solutions and preparing asset data strategies as part of wider asset management strategy/policy development and implementation assignments.

2. EA Technology's Condition Based Risk Management (CBRM) Methodology

Throughout EA Technology's history, major areas of activity have included the study of degradation and failure modes and the development and application of condition assessment procedures for network assets. A lot of work has been carried out to build a detailed understanding of the relationship of equipment specification, maintenance regimes, environment and duty with degradation, performance and, ultimately, asset failure.

Since 2000, a major area of activity has been the development and application of condition-based processes to assist companies to manage ageing assets. The CBRM methodology is one of the major outcomes and it continues to evolve to meet specific requirements of electricity companies; to date, projects have been undertaken with over 40 network operators around the world.

A timeline showing the key milestones in the development of EA Technology's condition based risk management methodology and products is shown in Figure 1.

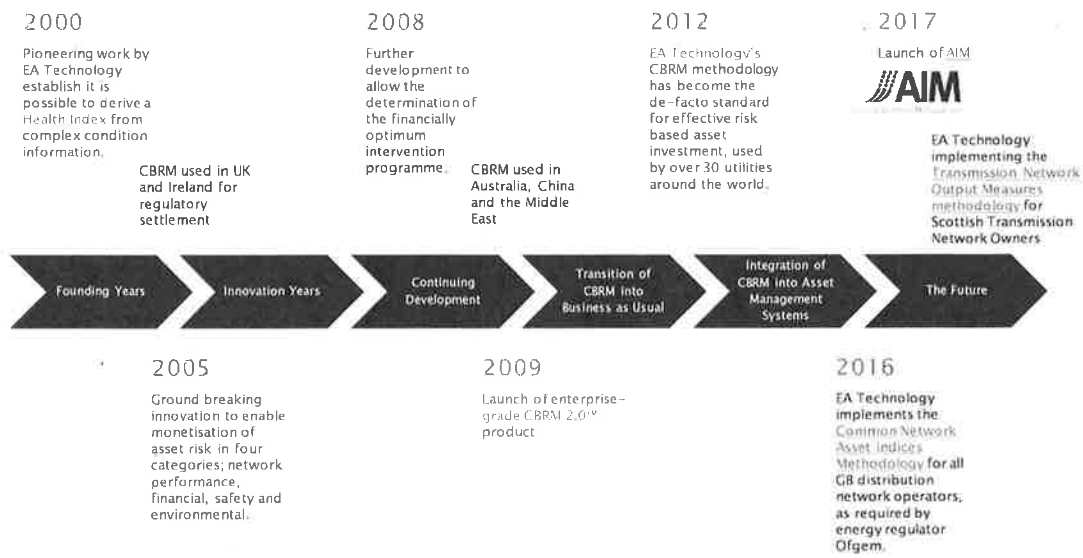


Figure 1 Timeline Showing EA Technology's Condition Based Risk Management Activities

3. Common Network Asset Indices Methodology

Within Great Britain, Distribution Network Operators (DNOs) are regulated by Ofgem, a government appointed regulator. Ofgem use an economic approach to regulation by agreeing to a suite of performance-based targets and operating licence contractual terms with DNOs over a series of "Price Control Periods". These targets range from metrics which reflect customer experience, overall network performance through to capital and revenue allowances.

The GB energy regulator Ofgem introduced regulatory reporting requirements for GB Distribution Network Operators for the regulatory period running from 2015 to 2023 (referred to as RIIO-ED1). RIIO (Revenue = Incentives + Innovation + Outputs). This marked a significant shift away from the previous RPI-X regulatory approach aiming to reduce costs within the utility sector to a more outcome-based regulatory reward system.

In order to facilitate these changes, a number of modifications to the requirements placed on network operators via their operating licences have been introduced. These include the requirement for DNOs to jointly develop a common framework such that DNOs adopt a common approach to the evaluation of asset health and criticality. DNOs are now required to report information on asset health and criticality using this common framework. This enables Ofgem to be able to make direct comparisons between each of the GB licence holders.

Most of the GB DNOs already had CBRM decision support tools developed in conjunction with EA Technology. Thus, CBRM was the logical starting point and EA Technology was invited to join the network operators' working group to develop the new common reporting standard, referred to as the Common Network Asset Indices Methodology (CNAIM or the Common Methodology). The output is similar to that from CBRM, but the CNAIM methodology is a simpler pragmatic approach that considers critical inputs for optimum results.

Following Ofgem's approval of the methodology, EA Technology developed a suite of 25 CNAIM models and worked with each of the DNOs to implement the methodology and embed it within their organisations.

4. Scope of involvement to date and length of contract

EA Technology was engaged with Toronto Hydro-Electric System Limited (THESL) on 20th June 2017, to review the progress THESL had already made with the new ACA investment models. This involved remotely conducting a detailed desktop review of the ACA models for Submersible Transformers and Overhead 3-phase Ganged Switches, and a higher-level data input and calibration review of a further 3 asset class models.

Following this review, EA Technology recommended a series of training sessions, and the concept of asset lifecycle in the context of CBRM was introduced. This led EA Technology onto providing THESL with a detailed understanding of the underlying CBRM methodology in order that THESL were able to understand the CNAIM linkage between asset health, probability of failure and risk. THESL have also gained an understanding of what the key objectives for CNAIM are within the GB regulatory environment, the way in which performance is measured in the GB distribution network operators, and the way in which optimised financial investment programmes are created.

EA Technology has provided an ongoing support service role from the last quarter of 2017, up to the point where THESL's new ACA models were frozen during quarter 1 in 2018. During this period, EA Technology has reviewed the types of input data THESL have used to develop the new generation of ACA models, considered the model outputs and calibration values based upon an ongoing dialogue between both organisations.

5. Alignment of models and next steps...

During the development of the new Asset Condition Assessment models produced by THESL, EA Technology have provided a series of training sessions which have explained the underlying philosophy and methodology in some detail. THESL's level of enthusiasm and interaction has been consistently good, which demonstrates a high level of commitment, and a genuine willingness to develop both their asset management knowledge base and a superior way of working into the future.

The effort placed into both the interaction with EA Technology and the development of the new ACA approach appears to have delivered a solid foundation which can easily be built on. THESL have demonstrated a clear understanding of the concepts behind the GB's Common Methodology, and this is evident by the way THESL have made sensible and constructive local modifications to model input data streams, and on occasion have also sought to adjust model architecture to reflect the differences of asset ownership and operation between Great Britain and Canada.

EA Technology has been party to a number of discussions in which local variations have been identified and subsequently agreed. These variations, and therefore the models developed by THESL, are in the opinion of EA Technology, consistent with the underlying objectives and principles of the CNAIM methodology.

As with the vast majority of projects of this nature, the initial development of ACA style investment decision support tools are often limited or restricted by the type, quality and/or volume of input data available to drive the calculation algorithms – and in this regard THESL can be regarded as one of EA Technology's typical customers. We would expect that following a period in which the new ACA methodology "beds-in" (matures) within the organisation, existing asset inspection, maintenance, operational, and investment policies and procedures may be revised in order to capture more asset specific data and new opportunities to further improve the ACA model capability.

EA Technology consider this to be a natural process in which models will incrementally improve over time as the benefits of this approach are realised.

General Observations, & Wider Concerns... ACA Model Review

Introduction

THESL are currently undertaking an asset management led project to introduce a new approach to asset condition assessment into their organisation. THESL have identified a UK based methodology, referred to as CNAIM, (Common Network Asset Indices Methodology) as the basis upon which their new condition assessment practices could be based.

Over the last quarter of 2017, significant advances have been made in the design and development of THESL's new ACA models. To date a total of 19 asset class models have been forwarded to EA Technology for review. This is a massive achievement! EA Technology have been impressed with the way in which, following some initial training, THESL have now embraced the CNAIM methodology and are able to design and create revised ACA models. Whilst THESL's models are currently limited to asset health scores for the present day and health score estimates into the future, and do not include PoF, risk or interventions, it should be noted that there are not many organisations who have achieved this feat with so little external input - well done!

Document Scope

This document provides EA Technology the opportunity to draw upon its broader experience in the fields of both asset condition assessment and the investment modelling arena/space. The primary purpose of this document is to identify any areas for further consideration along with any points of concern which EA Technology consider may require improvement so as to aid the "defend-ability" of the revised ACA models and their outputs.

The points raised in this document are not intended as a criticism of THESL. Rather, these points are presented and raised through a genuine desire to assist THESL succeed, and embed the revised ACA model work into business as usual which hopefully, in due course, will obtain favour with the regulatory authorities.

These observations are intended to be constructive, and are based upon our experience of other appointed 3rd parties scrutinising similar EA Technology created deliverables for other customers around the world.

It is hoped that by raising these observations now, and applying a little time and thought at this point, that a lot of time, energy and resource can be saved further down the line should THESL find themselves in a situation whereby they need to justify stated investment needs or, worse still, rigorously defend financial authorisation applications!

Points for consideration / discussion...

#1 - Asset definition & Model Boundaries

Second only to the core philosophy which underpins CNAIM/CBRM, the next most important thing which needs to be made clear to any reader/asset manager/regulator is the definition of the asset being considered within each of the modelling assessments, and the boundary (and where appropriate the limitations) of any ACA investment model.

Within the review work recently undertaken, there have been a couple of examples of where RCM worksheets have stated what limitations the RCM review has been conducted to.

However, no explicit statements have been found in either: -

- The ACA model design documentation
- The supporting ACA model documentation
- The Operating context documentation
  (which specifically relates to the ACA rather than RCM work)
- The ACA model output extracts/documentation.

This is a clear area for improvement!

Why does this matter?
With specific asset classes such as Transformers with tapchangers, limiting the assessment to only one main component may well affect the average lives, condition points, failure modes, risk calculations and ultimately the range of potential interventions which could be made available as model sophistication is enhanced and asset management capability improves.

Where limitations are applied, such as with the high-pressure air creation and distribution system associated with air blast circuit breakers. This may be considered reasonable as long as the management mechanism to ensure satisfactory condition and performance are maintained are clearly understood and has stated as dependants (i.e. the ABCB's).

In the case of asset classes such as pad mounted transformers or withdrawable circuit breakers, limiting the focus of the condition assessment to just the moving portion of each device is likely to raise questions and THESL may struggle to defend this position.

#2 – EOL criteria
The next comment runs along a similar vein to the last, in that readers/assessors of the ACA models also need to understand the condition criteria or combination thereof which THESL would consider to represent "End of Life" (EOL). This observation applies to the majority of models whereby EOL statements are either missing or are not explicitly clear.

There is not always a clear separation between (tactical) routine maintenance and a more strategic process of capital investment in either complete asset replacement or partial intervention. This situation does seem to keep re-occurring, and is perhaps best explained when considering a multi-panel switchboard; for example a 10 panel HSS Eclipse, a 10 panel Siemens 8DA10, or a 10 panel Hawker Siddeley HG12.

Under what circumstances would THESL consider the replacement of the entire switchboard? The RCM study states what the proposed criteria would be against an individual moving portion, but not the entire switchboard. This can potentially lead to confusion between routine maintenance and capital investment.

Examples of this can also be seen within the civil assets reviewed. Cable Chambers and Vaults appear to be subject to specialist civil engineering assessments (and quite rightly so!) However, the output from this condition assessment is unclear as to whether any issues can be addressed by routine maintenance or significant capital investment will be required... Can these assets be saved?

Previous experience suggests that it is unlikely that a network operator would (or for that matter would be allowed to) replace a substation building upon discovering a door hinge in a bad condition – but, without providing this context, THESL may lead others into forming this impression! THESL should consider whether the data points used to determine asset health scores provide the correct blend of "tactical" and or "strategic".

#3 – HI Banding Definition
Below is one example of a THESL Health Index Banding definition table.

Band	Definition
HI1	New or good condition
HI2	Minor deterioration in serviceable condition, may require assessment
HI3	Moderate deterioration, require assessment and monitoring
HI4	Material deterioration, consider intervention
HI5	End of life, intervention required

Minor editorial changes to these definitions are not uncommon, and often take place to reflect "local dialects" or "regional terminology". During the course of this project, the definition wording has been revised so as to provide more "clarity and certainty" about the meaning of each Health Index Band.

THESL may wish to revisit the HI2 definition to amend the "may require assessment" statement – either assessment is to be undertaken or it is not. It is suggested that THESL should add a standard activity to the regular model review process to look for and engineer out such anomalies.

#4 – Calibration of Average Life
The average life calibration values which have been set within the models have been broadly set in line with reports prepared for THESL by an external consultant. In almost every ACA model the approach THESL have taken has been to use the external consultant report as a broad brush.

Whilst THESL are in the early stages of developing condition assessment models the use of simple rules is acceptable. However, this calibration input could be regarded as "low hanging fruit", and should be refined. Ordinarily, average life calibration is set by dividing the asset population into sub-groups. These may be by manufacturer/type, generation of device, decade of manufacture, insulation type etc.

Traditionally assets which are used to form electrical transmission and distribution networks tend to have long (40 years plus) service lives. It is also normal to experience a number of infant mortality failures due to either imperfect asset design, material selection or through external influences such as mal-operation, vandalism or the weather.

Average life calibration should be kept under regular review and be relevant to the asset population which remain in service at the time of review. A report which states that the average expected service life for a particular device type may be in the region of 30 years maybe useful when the assets are introduced to the system. However, after 45 years of active service, a stated value of 30 years is almost meaningless, and will be very difficult to defend when challenged – especially when the vast majority of the asset population remains happily in service!

#5 – Location Calibration
More "low hanging fruit" can be found in the area of locational data. THESL are understood to be working on this at the moment, so this will be brief…

Look to develop cause and effect relationships between attributes which relate to asset location. This may be in the from of a "10% expected service life reduction" in circumstances where assets are "exposed to road salt or prevailing wind direction", or are subject to "poor ventilation" or perhaps "prone to flooding"?

Beware of "big data" approaches… Asset life reductions caused by "commissioned on a Tuesday, by a male engineer with blue boots". It may be possible to get this out of a large enough data set, but this doesn't make it true!

#6 - Calibration of Duty & Counter Readings
An ideal input into CNAIM/CBRM models which reflects circuit breaker or tapchanger asset duty can be found by using the counter readings taken directly from the device.

Whilst operation counter readings form the ideal basis for a duty factor, care should be taken to ensure that the counter reading does not double count against the asset age. It stands to reason that the older an asset gets, the larger the number of operations it will naturally be expected to have performed. Therefore, any counter readings should be compared upon a common basis; for example, an annualised operations count. This will enable devices and sites which work hardest to be identified.

This is an area of improvement which exists in THESL circuit breaker, tapchanger and air blast circuit breaker models.

#7 – Maintaining ACA Model Quality
During the Stage 1 model review process, EA Technology identified several errors within the ACA model equations and algorithms. The issues highlighted have subsequently been corrected. It should be noted that the high-level model reviews undertaken during Stage 3 of the project did not involve verification of any of the algorithms.

THESL have accepted that the models built during this rollout phase of the project have been vulnerable to poor input data quality – and there is little if any "work flow" protection currently within the models. THESL are predominantly working upon the basis that the source data will be of a sufficiently high enough quality that errors will not affect the process flow of any health score derivations – which is a risky route to take!

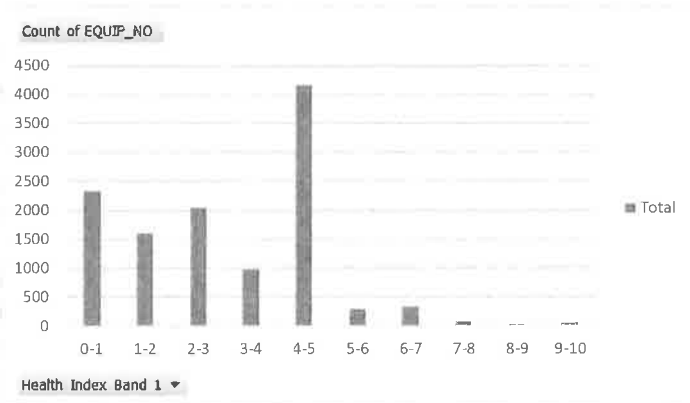
The financial value of the decisions which will potentially be made off the back of the ACA health score calculations are not insignificant. Therefore, EA Technology recommend that any programming code, equations or algorithms are made as robust as possible. As a minimum, all code should be able to deal with blank inputs and poor data quality in the future.

It is suggested that a "No Result" category should be created for assets that do not have a credible year of manufacture (i.e. YOM = 1900, or asset age is 117 years or 2017 years).

The use of simple rule sets, stock phrases and data dictionaries can help prevent data pollution, and make a contribution to the integrity of the ACA model outputs.

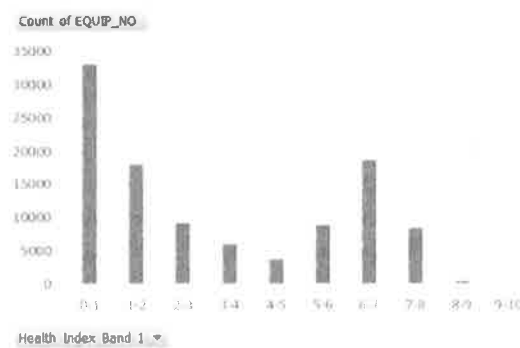
#8 – Model Alignment

The ACA models reviewed in Stage 1 of the project work from a mechanical point of view but the outputs appear to be "untested".



Health Score profile – Vault Transformers

Current Health	Count of EQUIP_NO
0-1	33085
1-2	18049
2-3	9300
3-4	6109
4-5	3786
5-6	8982
6-7	18737
7-8	8433
8-9	450
9-10	210
Grand Total	**107141**



Wood Poles Health Score Profile

Above are a couple of examples of health score profiles which could be regarded as either providing an untested view of THESL's asset base or they paint a very serious investment need.

The ACA model review has uncovered a number of potential future investment walls, which give cause for concern and a clear priority order with which to focus future model development.

Implementing a number of the (low hanging fruit) calibration enhancements should help improve the picture presented by these health score profiles

Bad probably isn't that bad

Equally don't forget about the good profiles either... are they really that good?

#9 – Specification of THESL Equipment

During the review project, EA Technology have been concerned by some of the procedural, operational and asset management based issues which THESL have presented. One example of this is in relation to submersible transformers, where THESL are only expecting to obtain a useful service life of between 6 and 8 years for new "Cam-Tran" transformers.

THESL have observed that when subjected to moisture or partial submersion in water the speed at which corrosion takes hold, and the rate of external tank degradation takes place is completely unacceptable, and has been for a long period of time.

When challenged as to why this supplier is still used, THESL described a loose/informal partnership approach to issue resolution which has involved the adoption of the manufacturers' recommendations to supply new devices with a stainless-steel transformer tank.

Certainly, this will reduce the rate at which corrosion takes hold, slightly. However, in EA Technology's view will not have the effect of extending the expected serviceable life from 6-8 years to the 33 to35 year expectation.

EA Technology would be happy and willing to explore this area in more detail with THESL, and would be delighted to offer our services to assist THESL with defining and specifying plant and equipment specification(s) and or provide our expertise into THESL's procurement/purchasing procedures?

#10 – Equipment Selection

Following on from #9 above, THESL may also wish to consider the type of equipment that they employ, and the way in which it is used; for example, Air Insulated Pad Mounted Switches. THESL have specified and purchased switching devices which have a fault make capability of two operations. This leads to two separate lines of questioning:

1/ Is this considered to be appropriate given the devices intended network function? Could THESL consider/benchmark against the procurement and operational practices of other network operators to identify and adopt best practice?

2a/ Given the limitation of a maximum of two fault make operations, why are the number of operations carried out (normal and fault make) not recorded?

2b/ Does this situation, or a similar situation (perhaps to do with a total number of operations carried out?) exist with other network components within THESL's power distribution system?

EA Technology would be happy and willing to explore this area in more detail with THESL, and would be delighted to offer our services to assist THESL with reviewing and improving existing

defining and specifying plant and equipment specification(s) and or provide our expertise into THESL's procurement/purchasing procedures? operational practice(s), data collection and recording processes, or undertaking an asset management system review?

#11 – Condition Point Calibration & established THESL practices
A number of models have been found to contain condition point calibrations for assets "in need of follow-up" which return higher factor values than assets with confirmed deficiencies.

Whilst EA Technology understand that this has been done in order to lower the overall health score for assets which have been added to future investment delivery plans; thereby elevating the health scores of assets with known deficiencies which do not currently feature on any intervention programme. This practice is not recommended as in the event that the investment delivery programme fails to deliver as planned, or regular ACA model review makes changes to model calibration, then there is a risk of assets with known deficiencies being lost within the noise of the broader asset population – and ultimately this may result in asset failures as they slip through the asset management net.

Calibration alignment in this way is regarded as not being within the spirit of the underlying philosophy/methodology, and would not be endorsed by any independent assessor.

One approach which could be considered more appropriate would involve calibrating the condition point as the underlying methodology intended, and then adding an additional field or two into the asset database/output results that flags assets which already appear in future investment plans. THESL may also consider it useful to identify within which future year any mediation is to take place. This way, regardless of how investment delivery programmes/functions perform, assets in poor condition remain on THESL's asset management radar – and any business or regulatory led reporting can be taken directly from the ACA model system without the need for further manipulation.