TPC Transaction Processing Performance Council

TPC-Energy Specification

Standard Specification
Version 1.2.0

June 2010

Transaction Processing Performance Council (TPC)

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Acknowledgments

The TPC acknowledges the work and contributions of the TPC-Energy subcommittee member companies: AMD, Dell, HP, IBM, Intel, Microsoft, Oracle, Sun, and Unisys. In addition, the TPC acknowledges the work of the Standard Performance Evaluation Corporation (SPEC) in the SPECpower documents, of which sections were used with permission in this specification.

TPC Membership

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Document Revision History

Date	Version	Description
December 2009	1.0.0	Specification Version as approved by Mail Ballot
February 2010	1.1.0	Many corrections and definition additions
April 2010	1.1.1	Minor corrections to definitions and clarifications.
June 2010	1.2.0	Corrections to Audit requirements and additional clarifications.

Typographic Conventions

The following typographic conventions are used in this specification:

Convention	Description
Bold	Bold type is used to highlight terms that are defined in this document
Italics	Italics type is used to highlight a variable that indicates some quantity whose value can be assigned in one place and referenced in many other places.
UPPERCASE	Uppercase letters names such as tables and column names. In addition, most acronyms are in uppercase.

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CLAUSE 0 -- PREAMBLE

0.1 Introduction

TPC-Energy Specification contains the rules and methodology for measuring and reporting an energy metric in TPC Benchmarks. This includes the energy consumption of system components associated with typical business information technology environments, which are characterized by:

- Energy consumption of servers
- Energy consumption of disk systems
- Energy consumption of other items that consume power and are required by the benchmark specification as components of the **System Under Test**.

0.1.1 Goal of the TPC-Energy Specification

The TPC-Energy specification augments all TPC Benchmarks by adding the methodology and requirements for including and reporting energy metrics.

The primary metric reported as defined by TPC-Energy is in the form of "Watts per performance" where the performance units are particular to each TPC Benchmark.

The measuring and publishing of the **TPC-Energy Metrics** in the TPC Benchmarks are optional and are not required to publish a TPC **Result**.

0.1.2 Restrictions and Limitations

Despite the fact that TPC benchmarks offer a rich environment that represents many typical IT applications, theses benchmark do not reflect the entire range of customer IT requirements. In addition, the extent to which a customer can achieve the **Results** reported by a vendor is highly dependent on how closely **TPC-Energy** measurements and configuration approximates the customer application. The relative performance and energy of systems derived from these benchmarks do not necessarily hold for other workloads or environments. Extrapolations to any other environments are not recommended.

Benchmark **Result**s are highly dependent upon workload, specific application requirements, and systems design and implementation. Relative system performance and energy utilization will vary because of these and other factors. Therefore, **TPC-Energy Result**s should not be used as a substitute for specific customer application benchmarking when critical capacity planning and/or product evaluation decisions are contemplated.

Benchmark **Sponsors** are permitted various possible implementation designs, insofar as they adhere to the model described and pictorially illustrated in this specification and other TPC specifications. Additions to the **Full Disclosure Report** **(FDR)** and Executive Summary documenting the energy measurement details, as specified in **Clause** 7--, must also be made available along with the reported **Result**s of the particular TPC Benchmark when reporting any of the **TPC-Energy Metrics**.

Comment: While separated from the main text for readability, comments are a part of the standard and must be enforced.

0.2 General Implementation Guidelines

The purpose of TPC benchmarks is to provide relevant, objective performance data to industry users. To achieve that purpose, TPC benchmark specifications require that benchmark tests be implemented with systems, products, technologies and pricing that:

- Are generally available to users.
- Are relevant to the market segment that the individual TPC benchmark models or represents (e.g., TPC-Energy augments other TPC benchmarks by adding energy metrics).

0.2.1 Benchmark Specials

The use of new systems, products, technologies (hardware or software) and pricing is encouraged so long as they meet the requirements above. Specifically prohibited are benchmark systems, products, technologies, pricing (hereafter referred to as "implementations") whose primary purpose is optimization of TPC benchmark results without any corresponding applicability to real-world applications and environments. The intent is to disallow "Benchmark Special" implementations that improve benchmark results but not real-world performance, pricing, or energy consumption.

The following characteristics should be used as a guide to judge whether a particular implementation is a Benchmark Special. It is not required that each point below be met, but that the cumulative weight of the evidence be considered to identify an unacceptable implementation. Absolute certainty or certainty beyond a reasonable doubt is not required to make a judgment on this complex issue. The question that must be answered is this: based on the available evidence, does the clear preponderance (the greater share or weight) of evidence indicate that this implementation is a Benchmark Special?

0.2.2 Benchmark Special Characteristics

The following characteristics should be used to judge whether a particular implementation is a Benchmark Special:

1) Is the implementation generally available, documented, and supported?
2) Does the implementation have significant restrictions on its use or applicability that limits its use beyond TPC benchmarks?
3) Is the implementation or part of the implementation poorly integrated into the larger product?
4) Does the implementation take special advantage of the limited nature of TPC benchmarks (e.g., limited duration, use of internal energy sources to the exclusion of supplied power, usage of unusual voltage or frequency in supplied power) in a manner that would not be generally applicable to the environment the benchmark represents?
5) Is the use of the implementation discouraged by the vendor? (This includes failing to promote the implementation in a manner similar to other products and technologies.)
6) Does the implementation require uncommon sophistication on the part of the end-user, datacenter facility manager, programmer, or system administrator?
7) Does the implementation use knowledge of the variability of the possible components to enhance the result in such a way as to be significantly different from what a typical customer would experience?
    - For example: If multiple components are available to be installed into the **Measured Energy Configuration** , are specific components selected to be the best (i.e. cherry picking) rather than typical or random?
    - For example: If multiple sources are available for components (e.g. multiple vendors are used for a single SKU) are the components selected representative of the majority of the mix delivered to customers? If a particular source would enhance the result, but is of very limited portion of shipping systems, it would not be representative.
    - In general, if the **Sponsor** has knowledge of the distribution of components through experimentation or documentation, then the extremes of the distribution must be excluded from use in the **Reported Energy Configuration** .
8) Is the electrical power distribution or cooling unusual or non-customary for the vendor, or unusual or non-customary to normal business practices?
9) Is the implementation being used (including beta) or purchased by end-users in the market area the benchmark represents? How many? Multiple sites? If the implementation is not currently being used by end-users, is there any evidence to indicate that it will be used by a significant number of users?

0.3 **General Measurement Guidelines**

TPC-Energy **Results** are expected to be accurate representations of system performance and energy consumption. Therefore there are certain requirements which must be followed. The approach and methodology are explicitly detailed in this specification and the TPC Benchmark Standards.

- The approach is an accepted engineering practice or standard.
- The approach does not enhance the **Results**.
- The equipment used in measuring **Results** must conform to the requirements in Clause 6.
- Fidelity and candor is maintained in reporting any anomalies in the **Results**, even if not specified in the benchmark requirements.

The use of new methodologies and approaches is encouraged so long as they meet the requirements above.

0.4 **Definitions**

A ____________________________

Accuracy Correction Factor

The Accuracy Correction Factor is a positive scale-factor to compensate for device inaccuracies and ensure that all reported measurements will not be less than the actual values.

Apparent Power

Apparent Power is a measure of the delivery rate of energy that does not include the effects of any reactance. In AC (alternating current) power system, some AC current (Amps) may flow into and back out of the load without delivering energy. This current, called reactive or harmonic current, gives rise to an "apparent" power (Volts x Amps) which is larger than the actual power consumed. This difference between the apparent power and the Real Power gives rise to the Power Factor. The Power Factor is equal to the ratio of the Real Power to the Apparent Power. Real Power is expressed in Watts and is calculated as Volts x Amps x Power Factor. This is different than the Apparent Power which is expressed as the Volt-Amp or VA rating.

Application

The term **Application** or Application Program refers to a computer program or piece of software designed to perform a specific task in a TPC Benchmark. This may include both commercial and **Sponsor** written code.

Application Server

An **Application Server** is a server that runs/executes/hosts the software that provides the interface between the user and the Database Server(s).

Attestation Letter

Attestation Letter: The **TPC Certified Auditor**'s opinion regarding the compliance of a **Result** must be consigned in an **Attestation Letter** delivered directly to the **Sponsor**.

Availability Date

The date when all products necessary to achieve the stated performance and energy characteristics will be available (stated as a single date on the **Executive Summary**). This is known as the **Availability Date**.

B ___________________________

Benchmark Special

Any aspect of the benchmark Implementation with the primary purpose of the optimization of TPC benchmark results without any corresponding applicability to real-world applications and environments.

C ___________________________

Compensated Value

The values reported for power after the application of the Accuracy Correction Factor

Crest Factor

Crest factor is the ratio between the instantaneous peak current required by the load and the RMS current (RMS stands for Root Mean Square, which is a type of average). This is used to determine a Power Analyzer's capability to incorporate the effect of spikes in the reported readings.

D ___________________________

Data Averaging Interval

Data Averaging Interval - The time period over which all samples captured by the high-speed sampling electronics of the power analyzer are averaged to provide the watts, volts, amps and power factor readings.

Data Reading Interval

Data Reading Interval - The time between unique samples provided by the analyzer.

Durable Media

Durable Media: One or more data storage media that is inherently non-volatile such as a magnetic disk or tape.

E ___________________________

Energy Measurement System (EMS)

EMS is the Energy Measurement System, a TPC provided software package that must be used in a **Test Sponsor's** implementation of the TPC-Energy Specification.

EMSConfigFile

EMSConfigFile is an XML file used by the EMS to determine the configuration of the power and temperature measuring components.

EMS-PTD

EMS-PTD is a version of the SPEC PTDaemon tool, provided under license from the Standard Performance Evaluation Corporation (SPEC), which includes extensions to meet the needs of the TPC. It connects directly to the Power Analyzer or Temperature Probe to obtain the readings.

EMS-PTD MANAGER

EMS-PTD MANAGER is a binary executable provided by the TPC for interfacing with the EMS-PTD and logging the readings acquired from the EMS-PTD,. It may also be generated by using the methods described in **EMSProjectFiles** with source code from **EMSSourceFiles**

EMSProjectFiles

EMSProjectFiles is a set of TPC provided files used to facilitate building the **EMS** packages in a **Test Sponsor's** environment.

EMS-Report Generator (RGen)

EMS-Report Generator Produces standardized reports from the EMS-PTDM logs for use in deriving energy consumption and temperature ranges.

EMSSourceFiles

EMSSourceFiles is the collection of TPC provided source code and header files.

Energy

Electrical energy is most commonly known as electricity. Electrical energy is the form of electricity that refers to the flow of power along a conductor providing the necessary power to run the System under Test. Electrical Energy is consumed at a certain rate and measured in KiloWatt Hours.

Energy Measurement

The term **Energy Measurement** is the measurement of energy taken during a **TPC Benchmark Standard** measurement interval or intervals in which the work being performed is used in the **Performance Metric** calculation.

Executive Summary

The term **Executive Summary** refers to the Adobe Acrobat PDF file required by each TPC benchmark. The contents of the **Executive Summary** are defined in each of the **TPC Benchmark Standards**.

External Power Source

External Power Source is the power distribution system provided by the customer in the data center to which the **REC** is connected. All energy consumed by the REC is provided by this source of power.

F ____________________________

Full Disclosure Report (FDR)

The **Full Disclosure Report** is a set of files required by the TPC Benchmark Standard including the following:

- A **Report detailing the results** in Adobe Acrobat PDF format,
- An **Executive Summary** in Adobe Acrobat PDF format,

Comment: The purpose of the **Full Disclosure Report** is to document how a benchmark **Result** was implemented and executed in sufficient detail so that the **Result** can be reproduced given the appropriate hardware and software products.

Fully Charged

A Fully Charged UPS refers to the condition when all the batteries in the UPS are charged to the maximum rated potential.

G ___________________________

H ___________________________

I ___________________________

Idle – Not being busy. Specifically, the state of the SUT when the SUT is ready to accept work, and will respond in a timely way

Idle Power

Refers to the average power measured on the REC during **Idle** state

J ___________________________

K ___________________________

L ___________________________

M ___________________________

Measured Configuration

The Measured Configuration is the set of components configured during the Measurement Interval to produce a Result in compliance with the TPC Benchmark Standard.

Measurement Interval

Measurement Interval: the period of time defined by the TPC Benchmark Standard used in the computation of the **Reported Throughput**.

Measured Energy Configuration (MEC)

The set of PMU's that are actually measured and used to determine the energy consumption for the REC

Miscellaneous Subsystem

The Miscellaneous Subsystem includes all **Power Measureable Units** that are required by the priced configuration which are not included in the measurements of the Database Server, **Application Server** or Storage Subsystem PMUs. This typically consists of PMUs such as Network switches, KVMs, Monitors, and other miscellaneous components.

N ___________________________

Nameplate Value

The manufacturer's specified value for the maximum power consumption of a Power Measureable Unit.

Network

Network – Devices used to interconnect subsystems or components of subsystems to facilitate communication and/or data transfer. TPC/IP over a local area network is an example of an acceptable **Network** implementation.

O ___________________________

P ___________________________

Part Number

See the definition of **Part Number** in the TPC Pricing Specification.

Performance Metric

The **Reported Throughput** as expressed in the units specified by each **TPC Benchmark Standard**

Power Measurable Unit (PMU):

A **Power Measurable Unit** is a Component or collection of Components of the REC that can be independently measured with a power analyzer. It must be possible to connect the unit into an External Power Source with no dependency on any other sources for power which are not being measured by a power analyzer.

Power Analyzer

The power analyzer is the device that will be connected or coupled to the power input of the **System Under Test** to collect power readings during the benchmark run.

Priced Configuration

Priced Configuration: The components priced in the **TPC Benchmark Standard** including all hardware, software and maintenance as required by the TPC Benchmark Standard.

Price/Performance Metric

The Price/Performance Metric as defined in each **TPC Benchmark Standard**

Q ___________________________

R ___________________________

Real Power

Power is a measure of the delivery rate of energy. In AC (alternating current) power system, some AC current (Amps) may flow into and back out of the load without delivering energy. This current, called reactive or harmonic current, gives rise to an "apparent" power (Volt x Amps) which is larger than the actual power consumed. This difference between the apparent power and the Real Power gives rise to the power factor. The Power Factor is equal to the ratio of the Real Power to the apparent power. Real Power is expressed in Watts and is calculated as Volts x Amps x Power Factor. This is different than the apparent power which is expressed as the Volt-Amp or VA rating.

REC Energy Consumption

This term refers to the total Energy consumed by the entire REC during the Measurement Interval. This value is calculated from measurements of the complete REC (all PMUs), or extrapolation from measurements of a subset of PMUs in the REC. When TPC Energy Secondary Metrics are quantified, this should also equal the sum of all of the Subsystem Energy Consumption values.

Reported

The term **Reported** refers to an item that is part of the **FDR**.

Reported Energy Configuration (REC)

The **Reported Energy Configuration** is based on the **TPC Benchmark Standard** "**Priced Configuration**". Support services and spares not installed are not included in the **Reported Energy Configuration**. Additional items not included in the "**Priced Configuration**", but included in a PMU in the MEC during measurements must be included in the energy consumption measured.

Result

Result - A performance test, documented by an FDR and Executive Summary submitted to the TPC, claiming to meet the requirements of an official **TPC Benchmark Standard**.

S ____________________________

Sponsor

The **Sponsor** is the **Test Sponsor,** as defined by the **TPC Policies**. The latest version of the **TPC Policies** can be found at http://www.tpc.org/information/about/documentation/doc.asp

Storage Subsystem

The Storage Subsystem is the **Power Measurable Unit**(s) storage subsystem for (Durable Media) storage of benchmark data.

Substitution

Substitution is the use of components in the **Priced Configuration** which are different than those used in the Measured Configuration. This also requires compliance with the TPC Pricing Specification.

Subsystem Energy Consumption

This term refers to the total Energy consumed by a subsystem of the REC during the Measurement Interval. This value is calculated from measurements of the complete subsystem (all PMUs), or extrapolation from measurements of a subset of PMUs in a subsystem.

Supporting Files

Supporting Files refers to the contents of the Supporting Files folder in the **FDR**. The contents of this folder, consisting of various source files, scripts, and listing files, are defined in Clause 7.

SUT Work Completed

This term refers to the total work completed by the SUT during all the Measurement Intervals. This is a computed value and is only used in the computation of the TPC-Energy Primary Metric.

System Under Test (SUT)

System Under Test (SUT) – is defined to be the sum of the components utilized in running a benchmark as specified in a **TPC Benchmark Standard**

T ____________________________

Test Sponsor

The **Test Sponsor** is the company officially submitting the **Result** with the **FDR** and will be charged the filing fee. Although multiple companies may sponsor a **Result** together, for the purposes of the TPC's processes the **Test Sponsor** must be a single company. A **Test Sponsor** need not be a TPC member. The **Test Sponsor** is responsible for maintaining the **FDR** with any necessary updates or corrections. The **Test Sponsor** is also the name used to identify the **Result**.

TPC Benchmark Standard

A **TPC Benchmark Specification** approved by the **Members.** The specification is a written document that describes a workload, including implementation, execution, auditing and reporting requirements. A Specification may require the use of TPC-Provided Source Code.

TPC-Certified Auditor (Auditor)

The term **TPC-Certified Auditor** is used to indicate that the TPC has reviewed the qualification of the **Auditor** and has certified his/her ability to verify that benchmark **Results** are in compliance with a specification. Note that an **Auditor** may be certified for either a **TPC Benchmark Standard** or the **TPC-Energy Specification** or both. (Additional details regarding the **Auditor** certification process and the audit process can be found in Section 9 of the TPC Policy document.)

TPC-Energy Metrics

Refers to the reported Energy results for the TPC-Energy specification. Refer to **TPC-Energy Primary Metric** and **TPC-Energy Secondary Metric**

TPC-Energy Primary Metric

This term refers to the reported metric and is a ratio of the REC Energy Consumption per unit of work done by the SUT and is expressed as watts / (work per unit of time).

TPC-Energy Result

TPC-Energy Result is a **Result** which meets the requirements of the TPC-Energy specification and reports TPC-Energy Metrics.

TPC-Energy Secondary Metric

This term refers to the optional reported metrics of the REC subsystems and is a ratio of the Subsystem Energy Consumption per unit of work done by the SUT and is expressed as watts / work per unit of time.

TPC-Energy Specification

The TPC-Energy Specification is the most current version of this specification which has been approved by the TPC.

U ______________________________

V ______________________________

W ______________________________

X ______________________________

Y ______________________________

Z ______________________________

CLAUSE 1 -- OVERVIEW

1.1 Business and Application Environment

The TPC-Energy Specification applies to all published TPC benchmarks, namely; TPC-C, TPC-E and TPC-H. Each of these benchmarks represents a specific set of customer environments and details can be found in the relevant benchmark specification. For example TPC-E exercises database server transaction functionality for a financial environment that receives work requests from multiple sources.

From a market sizing standpoint, the TPC benchmarks span diverse end-customer business environments ranging from small-sized business to large-sized corporate IT datacenters. The TPC-Energy specification defines methodologies to determine energy efficiency for data processing servers deployed in these diverse customer environments.

1.1.1 SMB (Small/Medium business)

Small businesses are companies with fewer than 100 employees, and medium-sized businesses are companies with 100-1000 employees. Server administration for these businesses is typically represented by limited or no dedicated IT staff.

1.1.2 Large Business Enterprise

This segment is typically characterized by companies with greater than 1000 employees, and usually has a dedicated IT staff for deploying and managing servers in their datacenters. Most of these businesses tend to have a diverse set of application environments running on several different server platforms for serving corporate departmental needs. However, some of these large business environments are specifically tailored for a specific business operation, e.g. retail operations, stock brokerage, airline reservations, etc.

Many of these Large Businesses also have Branch Offices that are centrally managed and connected.

1.1.3 Applications

The set of server deployments prevalent in the above market segments spans transactional environments for web services, business logic or application services, and database/OLTP.

- Web/Application Services: These workloads represent business logic written for commercially available Managed Runtime environments (such as Microsoft .NET Framework or J2SE 1.4). A large number of functions have to be performed to manage such environments to support business functions such as product browsing and order processing.
- Decision Support: These workloads represent an information analysis application environment, that incorporate complex query processing on databases to provide business intelligence and analysis for decision making purposes, such as pricing and promotions, supply/demand management, profit/revenue management, customer satisfaction studies etc.
- On Line Transaction Processing: These workloads represent complex OLTP environments as found at companies such as wholesale suppliers who must manage, sell or distribute a product or service (e.g. car rental, food distribution, parts supplier, etc). The functionality of these workloads is centered on the activity of processing orders, which is a mixture of read-only and update intensive transactions. The data warehouse is usually stored in a relational DBMS.

CLAUSE 2 -- METHODOLOGY

2.1 Introduction

The intent of this methodology is to represent, as accurately as possible, the average amount of electrical power that is required to perform work on the corresponding REC. In the cases when a **Performance Metric** directly corresponds to the amount of work completed per unit time, the goal is to have a energy measurement corresponding to that work.

Power is the measure of energy consumption per unit of time. Performance is normally reported as throughput (i.e. units of work per unit of time). Both of those quantities are ratios.

2.2 Goals

The goals for measuring energy in TPC benchmarks are as follows:

- Provide the energy usage measurements that a typical customer of the particular systems benchmarked would consume.
- Provide energy metrics that are comparable between systems under test for a particular **TPC Benchmark Standard**.
- Provide for repeatable and documented measurements.
- Components selected for use should represent the majority of the target market (see Clause 0.2):
- Physical Environment must be representative of the business / **Application** environments:
  - Temperature
  - Humidity
  - Altitude / Pressure (above sea level <1.1 Atm)

2.3 Relationship to other TPC Benchmark Standards

2.3.1 Relationship to TPC Benchmark Standards

This specification is intended to supplement the existing **TPC Benchmark Standards** by specifying the requirements to measure and report energy metrics in conjunction with each of the individual benchmarks. However, if any energy metric is reported for a published TPC benchmark then this specification must be adhered to in its entirety.

2.3.2 Relationship to TPC Pricing Specification

This specification alters some of the requirements and rules of the TPC Pricing Specification and in the case of any conflict this specification will always take precedence. The intent is to add additional requirements and restrictions to the TPC Pricing Specification when required.

2.3.3 Definitions of the SUT Components

The SUT is defined by the **TPC Benchmark Standard**. This is the configuration on which performance measurements are done. This specification defines subsets of the SUT for use in individual energy measurements, e.g. PMUs, MEC, and Subsystems. These definitions may vary between benchmarks and may differ from the SUT subsystem definitions as defined in the **TPC Benchmark Standard**.

2.4 Derived Benchmark Performance Metrics

Because some TPC Benchmarks may compute the **Performance Metric** as work per unit time over multiple intervals or as a "figure of merit" that is not a direct expression of work per unit of time, some care must be taken in computing a single primary energy metric as energy per unit of performance.

2.4.1 Single Interval

For benchmarks with a single performance measurement interval, energy measurements made at the same time as the performance measurements provide the average power which is used in the calculation of the **TPC-Energy Metric**. In this case, the metric is calculated as the ratio of the REC Energy Consumptionand the SUT Work Completed.

2.4.2 Multiple Intervals

For multiple intervals, energy measurements can still be made at the same time as the performance measurements, but the total work completed must be derived by multiplying the TPC Benchmark Primary Metric for performance by the sum of the durations of all the intervals. Similarly, the amount of energy consumed during each interval must be combined.

Example 1:
When a Performance Metric is calculated using performance measurements from multiple time intervals of unequal duration, computing the ratios for each time interval and averaging the ratios, will not have the same result as summing the values over the time intervals and computing a ratio.

Interval 1 measurements: 10 transactions per second for 10 seconds and 200 watt-sec of energy consumed. (20 watts average)
Interval 2 measurements: 100 transactions per second for 100 seconds and 2500 watt-sec of energy consumed. (25 watts average)
The benchmark's defined **Primary Metric** for performance is used. If this particular benchmark's primary performance metric is calculated as the average of these two throughput rates, then the performance metric is (10tps + 100 tps)/2 = 55 tps

Correct calculation:

(REC Energy Consumption) / (SUT Work Completed)

(Total Energy for both periods) / (Computed throughput for the duration of both periods)

((2000 watt-seconds) + (250,000 watt-seconds))/(55 tps * (10 sec + 100 sec)) = 41.65 W/tps

Note: The EMS Report Generator (Rgen) reports the consumed energy in watt-seconds.

Incorrect calculation:

Interval 1 (10 seconds) computes to **2 W/tps** (20 W avg /10 tps).

Interval 2 (100 seconds) computes to **0.25 W/tps** (25 W avg /100 tps).

(2 W / tps + 0.25 W / tps) / 2 = 1.125 W / tps

2.4.3 Subset of Total Work

TPC Benchmark Standards define a workload that has a corresponding metric that may not reflect the entire work being accomplished. An example is when only the "new_order" transactions are counted as transactions in the TPC-C benchmark metric tpmC.

As long as the entire workload defined by the benchmark specification has a fixed distribution of rates that are linear in the transactions that are counted as part of the reported **Performance Metric**, it is possible to report an accurate energy metric for that TPC Benchmark Standard.

It is important to remember that the **Performance Metric** is a measure of work done by a system where multiple components contribute to accomplishing that work. So any component would have a corresponding linear relationship for its actual throughput to the overall throughput for the SUT. For example, a disk subsystem will have a throughput of I/O requests that have a linear correspondence to the transaction rate. Similarly, the total throughput of all the clients in a SUT would be correlated to the overall throughput for the SUT.

From queuing theory, the maximum throughput of a network of service centers is the maximum throughput of the bottlenecking service center. Because of this direct correlation, it makes sense to talk about the throughput of the SUT or the throughput supported by a complete subsystem of the SUT as the same.

2.5 REC Partitioning

The **Reported Energy Configuration** (REC) is based on the **TPC Benchmark Standard "Priced Configuration"**. The REC is then logically divided into subsystems that are divided into one or more PMUs. It is necessary to have consistent definitions for these divisions to allow for measuring and reporting of energy metrics for the subsystems and combining measurements taken at multiple connections to the source of power.

2.5.1 REC Components

The REC is composed of components that are categorized by functionality and the source of power. The energy measurements for TPC-Energy are measured at the input to the components of the REC. These individual components or set of components have one or more connections to the External Power Source of a typical datacenter.

2.5.1.1 Power Measurable Unit (PMU)

A **Power Measurable Unit** is a Component or collection of Components of the REC that can be independently measured with a power analyzer. It must be possible to connect the unit into an External Power Source with no dependency on any other sources for power that are not being measured by a power analyzer.

Comment 1: It is entirely possible for a PMU to be comprised of multiple smaller PMUs. For example, a storage drawer that has an independent power cord to connect to AC power can be a PMU. A tower with a power distribution unit that has multiple storage drawers plugged into it can also be a PMU.

Comment 2: The term, PMU, does not mean "single power cord". If an entity connects to multiple External Power Sources that cannot be separated during normal operations, then the PMU must be measured with all such power sources in operation. For example, redundant power supplies that are designed to each hold 50% of the load during normal operations, but that could operate in suboptimal mode if one failed.

2.5.2 REC Subsystem Categories

When REC Subsystem metrics are reported, they must be reported as **TPC-Energy Secondary Metrics** for all categories specified in the following clauses. When the TPC Benchmark Standard priced configuration does not include reporting a particular Subsystem category, or combined Subsystem categories, then the non-included subsystems metrics are reported as "N/A".

2.5.2.1 Database Server Subsystem

The **Database Server** is the **Power Measurable Unit**(s) that runs/executes/hosts the commercially available database management software that implements (operates on) the database schema, data population and transactions of the TPC Benchmarks. This may also include a limited amount of storage and networking components not separately measurable from the Database Server energy.

2.5.2.2 **Application Server** Subsystem (Middle Tier Server)

The **Application Server** is the **Power Measurable Unit**(s) that runs/executes/hosts the software that provides the interface between the simulated user and the Database Server(s). This may also include some storage and networking components not separately measurable from the **Application Server** energy. The **Application Server** functionality includes, but is not limited to the following:

- Multiplexes many user requests into single Database Server requests
- Participates in Distributed Transactions (e.g., start, rollback, commit)
- Provides secure client/server interactions
- Manages **Application** state

2.5.2.3 Storage Subsystem

The Storage Subsystem is the **Power Measurable Unit**(s) storage subsystem for storage of benchmark data. Included, but not limited to, are any and all storage cabinets/bays/towers/external controllers that are required to be included in the **REC**.

All of the **Durable** storage and associated components, separately measurable from the Database Server(s) and **Application Server**(s) is considered to be the Storage Subsystem.

2.5.2.4 Miscellaneous Subsystem

The Miscellaneous category includes all **Power Measureable Units** that are required by the priced configuration and are not included in the measurements of the Database Server, **Application Server** or Storage Subsystem PMUs. These PMU's may optionally be included in the measurements of other Subsystems when the additional power consumption is less than 10% of the overall load of that particular subsystem.

CLAUSE 3 -- METRICS

3.1 Introduction

The **Energy** required to perform the work defined in a benchmark specification will be quantified by a variety of methods. The intent is to acquire enough instrumentation information to accurately represent the total energy consumed to complete the entire workload as defined by the **Primary Benchmark Specification**.

This information is in the form of a **REC Energy Consumption** for the entire REC. **Subsystem Energy Consumption** specific to each of the subsystems of the REC and may also be provided in addition to the **REC Energy Consumption**.

The **TPC-Energy Metrics** are a measure of the total energy taken to complete the workload task as defined in the **TPC Benchmark Standard**, and is reported as a ratio of the average power to the **Performance Metric**.

The basic formula for calculating the TPC-Energy metrics is the REC Energy Consumption divided by the total SUT Work Completed. Each of these must be determined appropriately for each type of TPC-Benchmark.

3.2 TPC-Energy Primary Metric

3.2.1 Power per performance throughput units.

The TPC-Energy Primary Metric is a ratio using the total energy consumed for all required measurement intervals in the numerator, and using the normalized work completed based on the Performance Metric of a TPC Benchmark Standard as the denominator of the ratio.

3.2.1.1 When the **Performance Metric** is a direct or linear measure of the amount of work completed, the **TPC-Energy Primary Metric** is calculated from energy measurements taken during the Benchmark **Measurement Interval** or intervals in which the work is being performed.

- The **TPC-Energy Primary Metric** will be similar to the price/performance metrics defined for other TPC benchmarks, where smaller is better.
- The **Performance Metric** needs to be multiplied by the duration of each measurement interval (to renormalize the work from the work per unit time). The results are summed for all the intervals to compute the SUT Work Completed.
- The total energy consumed for the entire REC must be derived for each measurement interval, which is the sum of each energy sample. Each energy sample is computed by the measured wattage multiplied by the sample duration. The **REC Energy Consumption** is then the sum total energy consumed during all of the measurement intervals.
- When the TPC Benchmark Standard primary metric is expressed in time units other than seconds, convert the **REC Energy Consumption** to the same time units.
- The **TPC-Energy Primary Metric** is computed by dividing the **REC Energy Consumption** in watt(time unit)s (e.g. watt-seconds, watt-hours) by the **SUT Work Completed** in units of work (e.g. transactions, queries). The reported metric will be in Watts/Work per unit of time (e.g. watts/KtpmC, watts/tpsE).

  Example

A TPC-C result of 139,693 tpmC is completed over a period (measurement interval) of 120 minutes using 75,780,000 watt-seconds of energy (REC Energy Consumption). At the rate of 139,693 tpmC for 120 minutes,16,763,160 New Order transactions were completed and is the total SUT Work Completed. Since the TPC-Benchmark Primary Metric time-interval is expressed in minutes, the reported watt-seconds by RGen needs to be also in minutes (watt-minutes). 75,780,000 watt-seconds of energy is divided by 60 to convert to 1,263,000 watt-minutes. The TPC-Energy metric for TPC-C is expressed in KtpmC so the SUT Work Completed is converted to K-transations (1000 transactions) by dividing by 1000. The calculation 1,263,000 watt-min/16,763.160 K-transactions results in 75.3 watts/KtpmC.

(75,780,000 watt-seconds / 60) / (16,763,160 transactions / 1000) = 75.3 watts/KtpmC

3.2.1.2 When the **Performance Metric** is not a direct or linear measure of the amount of work completed, the **TPC-Energy Primary Metric** is calculated using the same methodology.

In cases where the **Performance Metric** for a benchmark standard is not a direct calculation of work per unit time (Ex: Geometric Mean), the same techniques will be applied to calculate the **TPC-Energy Primary Metric**. The **SUT Work Completed** must use the Primary Performance Metric (expressed as a throughput rate) multiplied by the sum of the durations for all Measurement Intervals used to calculate the Performance Metric.

Example:
A TPC-H result of 12,226 QphH@300G is reported with a power run of 15,910.6 QppH@300G over a period of 0.75388 hours (2714 seconds) and a throughput run of 9,394.0 QptH@300G over a period of 4.21544 hr (15,175.6 seconds). The total energy consumption measured over those two intervals, was 3,731,760watt-seconds for the power run and 24,660,360 watt-seconds for the throughput run. Even though the 12,226 QphH@300G is not the actual throughput for both intervals, but a computed value based on the requirements of the Benchmark Standard, it is a figure of merit that is represented as the throughput. The work completed in the benchmark is computed as the total time spent in both measurement intervals (power and throughput) multiplied by the QphH value. The TPC-Energy Primary metric for this result would then be (62196watt-seconds + 411006watt-seconds) / 60754.19 queries reported as 129.81 watts/KQphH@300G.

(0.75388 hrs + 4.21544 hrs) * 12,226QphH@300G = 60,755 queries [SUT Total Work]

(3,731,760 watt-seconds + 24,660,360 watt-seconds) / 3600 seconds = 7886.7 watt-hours

7886.7 watt-hours / (60755 queries / 1000) = 129.81 watts/KQphH@300G

3.3 TPC-Energy Secondary Metrics

The TPC-Energy Specification defines additional secondary metrics. The purpose of these secondary metrics is to allow more detailed comparisons and analysis of the result.

3.3.1 Detailed breakdown of average power by subsystem

TPC-Energy Secondary Metrics corresponding to the energy consumption for each of the REC subsystems may also be reported if the measurement of each subsystem is possible.

Energy measurements for individual REC subsystems taken during the Benchmark **Measurement Interval** or intervals in which the work being performed is included in the **TPC-Energy Secondary Metric** calculation

- The **Performance Metric** (throughput) needs to be multiplied by the duration of each measurement interval (to renormalize the work from the work per unit time). The results are then summed for all measurement intervals to compute the SUT Work Completed.
- For each of the REC subsystems, the total energy needs to be measured during each interval (samples can be summed and multiplied by the sampling period). The **Subsystem Energy Consumption** is the energy consumed by each subsystem during all of the measurement intervals.
- The **TPC-Energy Secondary Metrics** are computed by dividing the **Subsystem Energy Consumption** by the **SUT** **work completed** for each subsystem. The reported metric will be in Subsystem-name Watts/Work per unit of time, where Subsystem-name is selected from DBServer, AppServer, Storage and Misc.

Example: Using the TPC-C example from clause 3.2.1.1, assume that the Database Server consumed an average of 748 watts for the 120-minute measurement interval, and a reported 5,400,000 Watt-seconds by the RGen. The 5,400,000 watt-seconds is equal to 90,000 watt-minutes (5,400,000 / 60 seconds). The TPC-Energy Secondary Metric for the Database Server is 90,000 Watt-min/(16,763,160 transactions / 1000) = 5.37 DBServer watts/KtpmC.

Note: The average watts reported is NOT used in the calculation but is provided by the EMS Report Generator for use in applying the correction factors for the device.

- The **TPC-Energy Secondary Metric** will be similar to the TPC-Energy Primary Metric, where smaller is better.

As in pricing where the total price is the sum of the pricing of all the components, the energy consumed by the entire REC is the sum of the energy consumed by each subsystem to achieve the reported throughput (**Performance Metric**) or figure of merit (where a **Performance Metric** is not a true throughput). The sum of the **TPC-Energy Secondary Metrics** for all the REC subsystems should result in the same value as the reported **TPC-Energy Primary Metric** for the entire REC.

The following conditions prohibit the reporting of these secondary metrics:

- Use of a UPS when it is connected to multiple subsystems.
- When the energy of a subsystem is not completely measureable as a separate PMU, and more than 10% of a Storage, Database Server, or Application Server (Miscellaneous is not included in this requirement) subsystem's workload is not measurable separately from another subsystem. (An example would be when more than 10% of the storage devices I/O operations for the Storage subsystem are being performed by the storage devices within the Database Server subsystem and powered by the same power supply as the server memory and processors.)
- If a subsystem is not defined for a Benchmark Standard (e.g. the Application Server subsystem in TPC-H), secondary metrics are allowed for the remaining subsystems.

  Note: Proof must be provided to the satisfaction of the Auditor that the above 10% workload requirement is met.
- The Miscellaneous Subsystem PMUs may be included in the measurements of other subsystems, provided that the energy consumption increase is less than 10% of the Subsystem energy. This is for ease of benchmarking.

3.3.2 Idle Power

The numerical quantity for **Idle Power** is also required to be reported. This numerical quantity is defined as the measured energy consumption of the entire REC after the TPC Benchmark Standard workload has stopped for a defined period of time. The intent is to represent to a customer the amount of energy consumption of a REC in a state ready to accept work. This is useful to customers who have systems that have periods of idle but require the system to respond to a request for work at any time. This is reported in watts and calculated as the energy consumption in watt-seconds divided by the idle measurement period in seconds.

3.3.3 Acceptable measurement conditions for Idle Power

Since many systems have power savings capabilities, it is important to recognize that "ready to accept work" requires a quick response and not a lengthy initialization process before processing that work. Any idle power measurement must be made within a period of time (defined in Clause 5.2.4) of the SUT going idle.

To ensure that the SUT is ready to accept work, the criterion is that the start of work on newly submitted transactions (e.g. anything arriving after the SUT has gone idle) must not be unduly delayed by recovery from power saving states. Therefore, it is required that the response time of the first transaction processed after the idle period cannot exceed 1.5x the response time required by the benchmark specification.

For TPC-C , TPC-E and future benchmarks where 90th percentile response criteria are specified, a single transaction submitted after the idle period must not exceed 1.5x the 90th percentile response criterion for that transaction.

For TPC-H, where no response criteria are specified, the ACID query must be run on the full size database before the first power run, and must be executed again using a different O_Key after the idle period. The response time must be no longer than 1.5 times the initial query's value or less than 1 second

3.3.4 Database status

In addition to meeting the response time requirement for an idle system, the database software and associated storage volumes must be up and running during the idle power measurement. The requirement for up and running is defined as being an active task visible to the OS for immediate scheduling and the storage volumes must be visible to the operation system as usable storage.

No manual intervention is allowed to change the state of the software on the SUT to meet the response time requirement during an acceptable idle period.

3.3.4.1 Ordering of idle and active measurements.

To ensure that the SUT is ready to complete any new, offered load, the idle measurement must be made after the performance run measurements have been completed. This will ensure that all components necessary to complete the work are available and active. It will also ease the cost of benchmarking by not requiring any special setup of the SUT for a separate idle power measurement.

3.3.5 Idle measurement duration and the Maximum idle period

Once a SUT goes idle, power management features may reduce the power draw of the REC. The intent of this evaluation is to encourage power management that can reduce power draw of the REC as long as it does not violate the other requirements of this specification.To represent a ready but idle SUT, the idle measurement must be made within a fixed period of the SUT going idle. This time will allow the measurement to be completed easily.

The idle measurement is the average power draw during the idle period, as defined in Clause 5.2.4.

3.4 TPC-Energy Metric Scaling

TPC-Energy Primary Metric for each TPC benchmark has been scaled by factors of 1000, when required, to yield a metric between 1 and 3 significant digits to the left of the decimal point.

3.4.1 The TPC-C energy metric

The TPC-Energy Primary Metric for TPC-C is expressed in units of Watts/KtpmC. The **TPC-Energy Secondary Metrics** for TPC-C are also expressed in units of Subsystem-Name Watts/KtpmC for each subsystem

3.4.2 The TPC-E energy metric

The **TPC-Energy Primary Metric** for TPC-E is expressed in units of Watts/tpsE. The **TPC-Energy Secondary Metrics** for TPC-E are also expressed in units of Subsystem-Name Watts/tpsE for each subsystem

3.4.3 **The TPC-H energy metric**

The TPC-Energy Primary Metric for TPC-H is expressed in units of Watts/KQphH@Scale Factor. The **TPC-Energy Secondary Metrics** for TPC-H are also expressed in units of Subsystem-Name Watts/KQphH@Scale Factor for each subsystem.

3.5 UPS and PDU Measurements

3.5.1 **Uninterruptible Power Supply (UPS) and Power Distribution Unit (PDU)**

If a UPS or PDU is included in the priced configuration, it must be included in the **Measured Configuration** (MEC) for energy measurements.

3.5.1.1 Conditions For Energy Measurements with UPS

Measurements of the portions of the REC connected to a UPS must be measured at the input to the UPS. A UPS must not reduce the amount of energy supplied by the **External Power Source** as compared to the REC without the utilization of the UPS.

During the benchmark measurement interval, the following conditions must also be met:

- Batteries must be **greater than 90% charged** at the start**.**
- At the completion, batteries must be **charged** greater than or equal to the starting charge.
- Batteries must not be used to replace the External Power Source during any time during the measurements.
- All UPS events must be captured and be available for the Auditor.

3.5.1.2 Accounting for UPS(s) and Power Distribution Units (PDU) within subsystems

When a UPS or PDU is connected to a single subsystem or a portion of a single subsystem then the energy consumed by the UPS or PDU itself is included in the measurements of the subsystem to which it is connected.

When a UPS or PDU is connected to more than one subsystem, then the reporting of TPC-Energy Secondary Metrics of those subsystems is not allowed.

3.6 **Calculating Energy for PMUs not Measured**

When PMU's are not measured, the calculations for the non-measured components of the REC must employ the same methodology described below for both the Measurement Interval and the Idle Measurement.

3.6.1 **Subset of REC Measurements**

Energy measurements on a subset of the REC may be used for calculating the energy used on equivalent subsets. Each of the equivalent subsets not measured must have the same workload, software, hardware and interconnect of those selected for measurement.

For instance, measurements of a subset of the disk subsystem with the same workload can be used to calculate the energy used by other equivalent subsets of the disk subsystem.

"Equivalent PMU"s are **PMU**s which have the same workload, software, hardware and interconnect.

"Same Workload" is defined to be within **2%**.

3.6.2 **Extrapolation Methodology**

Any subset selected for measurement must be a **PMU**. When extrapolation is used to calculate the energy consumption of a **PMU**, instead of measuring the actual energy consumption, the following procedure must be used:

1) At least 2 Equivalent PMUs must be included in the **Measured Configuration**.

2) The Auditor selects two PMUs from the **Measured Configuration** to be measured for the extrapolation calculation.

3) The two measured PMU's energy must be within the required 10% variation of each other, for the set of unmeasured PMU's to be considered equivalent.

4) The calculated energy consumption for the unmeasured PMUs is assigned the value of the larger of the two measurements of the selected PMUs .

5) The total energy consumed for the full set of Equivalent PMUs is the energy consumed by the measured PMU's plus the energy consumed by the calculated unmeasured **PMU**s.

3.6.3 Priced and Measured Configurations are Identical

When the priced configuration and the **Measured Configuration** are identical, it is permissible to measure a subset of Equivalent **PMU**s. The energy consumption for the unmeasured Equivalent **PMU**s will be the extrapolated value(s) per Clause 3.6.2**.**

Note: The intent of this is for ease of benchmarking and simplifying energy measurements when configurations have multiple Equivalent PMUs.

3.6.4 Priced Configuration is not identical to the Measured Configuration

3.6.4.1 Increasing the number of Equivalent PMUs in the Priced Configuration

If the quantity of a **PMU** in the **Priced Configuration** is greater than the quantity in the **Measured Configuration**, then the energy consumption of the **PMU**'s being added into the **Priced Configuration** will be the extrapolated value(s) per Clause 3.6.2**.**

3.6.4.2 Substituting a set of PMUs in a Measured Configuration

If the priced configuration contains **PMU**s being substituted for **PMUs** in the **Measured Configuration** which are not Equivalent **PMU**s but have the Same Workload, then at least two Equivalent substitute **PMUs** must be present in the **Measured Configuration. The** energy consumption for the substitute **PMU**'s in the **Priced Configuration** will be the extrapolated value(s) per Clause 3.6.2**.**

3.6.4.3 Substituting a set of PMUs not in the Measured Configuration

If the priced configuration contains **PMU**s being substituted for **PMUs** in the **Measured Configuration**, which are not Equivalent **PMU**s and the measured configuration did not have at least two Equivalent **PMU**s, then the energy consumption for both the performance and idle calculations of the **PMU**'s being substituted into the **Priced Configuration** will be the manufacturer's specified Nameplate Value(s)**.**

3.6.4.4 Substituting components within a PMU

Substitution of components within a **PMU** causes the **PMU** to be modified and requires measurement of the energy consumption. When measuring energy consumption in TPC Benchmark configuration, the measurements are taken at the **PMU** level. Therefore, if substituting components within a **PMU**, the energy consumption is still measured at the **PMU** level. If a measurement of the modified **PMU** is not possible, then the substitution is disallowed. However, the modified **PMU** could be substituted per Clause 3.6.4.3.

3.6.5 Restriction on use of Nameplate values

Use of **Nameplate** values are not intended to represent a significant portion of the **REC Energy Consumption.** No more than 20% of the total **REC Energy Consumption** may be represented with **Nameplate** values in lieu of measurement or extrapolation**.**

CLAUSE 4 -- DRIVER / CONTROLLER SOFTWARE

4.1 Overview

The Energy Measuring System (EMS) is a TPC provided software package designed to facilitate the implementation of TPC-Energy measurements.

EMS provides:

- Software to interface to power instrumentation (power analyzers, temperature probes).
- Reliable logging of power and temperature readings.
- Synchronization of time.
- Standardized output log of data collected.
- Report generation
- Interface to **Sponsor** software for logging events and messages
- Interface to **Sponsor** software for displaying real-time data

This clause covers the constraints and regulations governing the use of **EMS**. For detailed information on **EMS**, the specific features and functionality and user instructions see Appendix A.

4.2 EMS Functional Diagram

The EMS consists of a single execution of the EMS controller and multiple PTD Managers and PTD executions. Each device taking measurements requires one PTD and one PTDM, which is controlled via the EMSC. The EMSC also provides connections for real-time displays and an interface to the **Sponsor**'s benchmark driver.

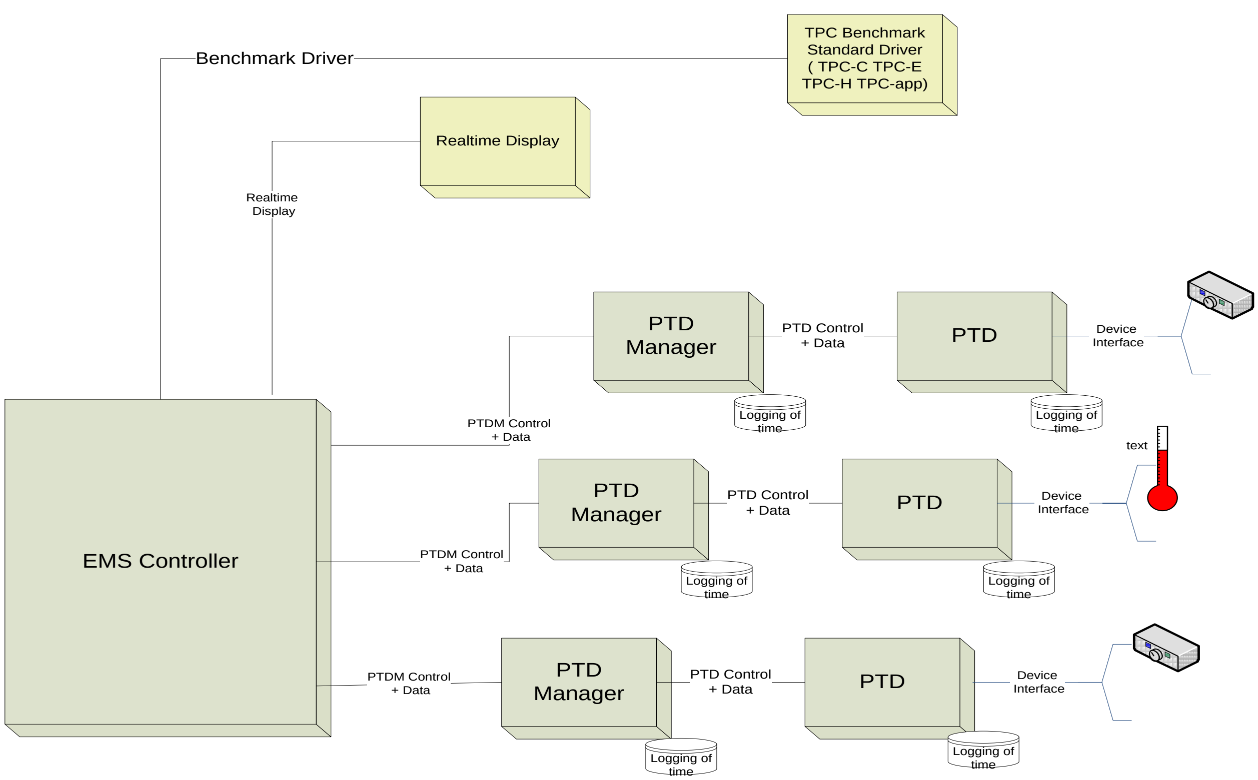

Figure 1 - EMS Functional Diagram

4.3 EMS Terms

4.3.1 EMS is the Energy Measurement System

EMS is the Energy Measurement System, a TPC provided software package that must be used in a **Test Sponsor**'s implementation of the TPC-Energy Specification. The software package is logically divided into three: **EMSProjectFiles**, **EMSConfigFile**

, and **EMSSourceFiles**.

4.3.1.1 EMS-ProjectFiles is a set of TPC provided files used to facilitate building the EMS packages in a **Test Sponsor**'s environments. These files are used by the compilers and/or development system to create the executable binaries for the target architecture and operating system.

4.3.1.2 EMS-ConfigFiles is a set of TPC provided text files containing configuration and device interface data.

4.3.1.3 EMS-SourceFiles is the collection of TPC provided source and header files.

4.3.2 EMS-PTD

EMS-PTD (Power and Temperature Daemon) is a binary executable, provided by the TPC under the license terms from SPEC. When executed, EMS-PTD uses **EMS-ConfigFiles** for the configuration of the devices, initializes power analyzers, and reads power or temperature data, and sends data to EMS-PTD Manager. Optionally the PTD can also log the data.

EMS-PTD is a binary executable provided by the TPC. EMS-PTD includes extensions to the SPEC PTDaemon tool, provided under license from the Standard Performance Evaluation Corporation (SPEC), which directly connects to the Power Analyzer or Temperature Probe to obtain the readings.

4.3.3 EMS-PTD MANAGER

EMS-PTD MANAGER is a binary executable, generated by using the methods described in EMS-ProjectFiles with source code from **EMS-SourceFiles**, including any extensions by a **Test Sponsor** (see Clause 4.4.5). When executed, **EMS-PTD MANAGER** uses **EMS-DataFiles** for the configuration and synchronizing controllers, initializes EMS-PTD, and reads and logs power and temperature data received from the EMS-PTD.

4.3.4 EMS-CONTROLLER

EMS- CONTROLLER is a binary executable, generated by using the methods described in EMSProjectFiles with source code from **EMSSourceFiles**, including any extensions by a **Test Sponsor** (see Clause 4.4.5). When executed, **EMS-CONTROLLER** is used for the configuration and synchronizing of one or more EMS-PTD Managers. It collects data from all the PTD Managers and synchronizes and formats data logs. It also provides real-time data for display purposes for use by **Sponsor** provided software. There is also an interface to the **Sponsor**'s benchmark driver.

4.3.4.1 Time Synchronization

The **EMS-Controller** must provide time synchronization for all the systems in the **EMS**. The time during logging must not drift more than 5 seconds for the duration of any measurement interval.

4.3.4.2 Reporting of Events

The EMS-CONTROLLER must record the time of events or errors of all the EMS modules. These are also communicated to all the PTD-MANAGERSs for logging synchronization.

4.3.5 **EMS-Report Generator (RGen)**

EMS-Report Generator is a binary executable, generated by using the methods described in EMSProjectFiles with source code from **EMSSourceFiles**, including any extensions by a **Test Sponsor** (see Clause 4.4.5). When executed, **RGen** produces standardized reports using the **EMSConfigFile** for the configuration and measurement data from the logs formatted by the EMS-CONTROLLER. It also performs data validation. In the case where Energy Consumption calculations require repeated Measurement Intervals, a report is generated combining the data from the Measurement Intervals (see Clause 5.3)

4.4 Compliant EMS Versions

4.4.1 Major and Minor Revisions

The major and minor revision of the specification and **EMS** must match. There is no requirement that the third level revisions match (see TPC Policies for specification revision information).

4.4.2 Existing Errors

Any existing errors in a compliant version of **EMS**, as provided by the TPC, are deemed to be in compliance with the specification. Therefore, any such errors may not serve as the basis for a compliance challenge.

4.4.3 EMS is written in ISO C/C++ and/or Java based on the following standards:

- ISO/IEC 9899:1999 Programming Language C
- ISO/IEC 14882:2003 Programming Language C++
- Java SE 6 - Java Programming Language

Failure of a compiler to properly compile **EMS** because of the compiler's non-conformance with the above standards does not constitute a bug or error in **EMS**.

4.4.4 Addressing Issues in EMS for benchmark submittal

If a **Test Sponsor** must correct an error or other issue in **EMS** in order to publish a **Result**, the following steps must be performed:

1) The error must be reported to the TPC, following the method described in clause 4.4.5, no later than the time when the **Result** is submitted.
2) The error or other issue and the modification used to resolve it must be reported in the FDR, as described in clause 7.3.4.3.
3) The modification used to implement the correction must be reviewed by a **TPC-Certified Auditor**.

Furthermore, the modification and any consequences of the modification may be used as the basis for a non-compliance challenge.

4.4.5 Process for Reporting Issues with EMS

EMS has been tested on a variety of platforms. The TPC does not guarantee that **EMS** is functionally correct in all aspects or will run correctly on all platforms. It is the **Test Sponsor's** responsibility to ensure **EMS** runs correctly in their environment(s).

4.4.5.1 Portability Issues

If a **Sponsor** believes there is a portability issue with **EMS**, the **Sponsor** must:

- Document the exact nature of the portability issue.
- Document the exact nature of the proposed fix.

- Contact the TPC Administrator with the above specified documentation (hard or soft copy is acceptable) and clearly state that this is an **EMS** portability issue. The **Sponsor** must provide return contact information (e.g. Name, Address, Phone number, Email).

The TPC will provide an initial response to the **Sponsor** within 7 days of receiving notification of the portability issue. This does not guarantee resolution of the issue within 7 days.

If the TPC approves the request, the **Sponsor** will be contacted with detailed instructions on how to proceed. Possible methods of resolution include:

- The TPC releasing an updated specification and **EMS** update
- The TPC issuing a formal waiver documenting the allowed changes to **EMS.** In the event a waiver is issued and used by the **Sponsor**, certain documentation policies apply (see Clause 7.3.4.3).

If the TPC does not approve the request, the TPC will provide an explanation to the **Sponsor** of why the request was not approved. The TPC **may** also provide an alternative solution that would be deemed acceptable by the TPC.

4.4.5.2 Other Issues

For any other issues with **EMS**, the **Sponsor** must:

- Document the exact nature of the issue.
- Document the exact nature of the proposed fix. The **Sponsor** must provide return contact information (e.g. Name, Address, Phone number, Email).
- Document the exact nature of the proposed enhancement
- Document any proposed implementation for the enhancement
- Contact the TPC Administrator with the above specified documentation (hard or soft copy is acceptable) and clearly state that this is an **EMS** enhancement suggestion. The **Sponsor** must provide return contact information (e.g. Name, Address, Phone number, Email).

The TPC does not guarantee acceptance of any submitted suggestion. However, all constructive suggestions will be reviewed by the TPC, and a response will be provided to the **Test Sponsor**.

4.5 EMSProjectFiles

The **EMSProjectFiles** provided by the TPC are meant to be used as a template to develop **EMS** environments. Use of **EMSProjectFiles** are optional.

4.6 EMS-ConfigFiles

Modification of the **EMSConfigFile** provided by the TPC is permitted but must still set options in accordance with the required measurement parameters. Changes to the configuration must be reported in the FDR, see Section 7.3.4.1

4.7 EMS-SourceFiles

Modification of **EMSSourceFiles** provided by the TPC is not allowed, except as permitted by Section 4.4.

CLAUSE 5 -- RULES AND PROCEEDURES

5.1 Introduction

This clause defines the execution rules and the methods for calculating the TPC-Energy Metrics and numerical quantities.

5.2 Measurement Intervals and Conditions

5.2.1 Overview

The **TPC-Energy Metrics** report energy consumption for the **REC** when the TPC workload is actually running.

5.2.2 Measurement Interval for TPC-Energy Primary Metric (full load)

The measurement interval for all TPC-**Energy Metrics** will be the same as the active measurement interval defined by the **TPC Benchmark Standard**.

5.2.3 Multiple Performance Measurements Option

When the REC Energy Consumption is not collected in a single Performance Run, multiple Performance Runs must be used to collect the required PMU energy data. When this option is utilized, the following requirements must be met:

5.2.3.1 All Performance Runs must meet all the TPC Benchmark Standard requirements.

Comment: The intent is that all the ACID and other requirements are still compliant during these Performance Runs. This also implies that any of these Performance runs could be used as the Reported Performance Run.

5.2.3.2 One of the Performance Runs used to collect the REC Energy Consumption data must be the Performance Run used to determine the reported TPC Benchmark Standard performance metric.

5.2.3.3 Every Performance Run used for energy measurements must have a TPC Benchmark Standard Primary Performance Metric within 2% of the reported value.

5.2.3.4 Every Mesurement Interval used for energy measurements must have a duration of at least 98% of the duration of the Mesurement Interval used for reporting the TPC-Benchmark Primary Metric.

5.2.4 Idle Measurement

Idle Power provides a measurement of the REC or subset of components in the ready-to-run state. The measurement must be taken with all software and hardware components ready to perform further full-load testing. The idle measurement must begin within 30 minutes of the completion of the all TPC-Benchmark data processing and will have a minimum duration of 10 minutes. Idle Power is a required reported Numerical Quantity.

5.2.5 Other Conditions

5.2.5.1 Power Source

The power source used to power the REC must be generally available. Each type of power source used during the benchmark measurements must be reported in the FDR. In the case where the measurements are made in an environment or location that is different than the location where the system is available and priced, the measured voltage must not be more than 15% above the nominal voltage in the location where the system is available and priced. All measured components must operate within the nominal supply voltage of the location in which it is available and priced.

Examples:

1) This allows measuring 230 volts, and selling and pricing the same system in a location that has a nominal voltage of 208 volts, provided that the power supply is rated to support both voltages.
2) This allows measuring 100 volts, and selling and pricing the same system in a location that has a nominal voltage of 120 volts, provided that the power supply is rated to support both voltages.
3) This would not allow measuring 120 volts, and selling and pricing the same system in a location that has a nominal voltage of 100 volts, even though the power supply is rated to support both voltages. This is due to the typical decrease in power supply efficiency when reducing the input voltage.

5.2.5.2 Temperature

The minimum temperature must be at least 20° C for the duration of all measurement intervals. The temperature must be measured at the airflow inlet expected to have the lowest temperature. The probe must be positioned within 100 mm of the air input grill.

This requirement does not apply to components that do not use ambient airflow for cooling. These components and the means for cooling must be documented in the FDR.

5.3 Required Data Collection

This section defines the execution rules and the methods for calculating the TPC-Energy Metrics, TPC-Energy Secondary Metrics, and numerical quantities.

5.3.1 Primary Metrics Data

In order to calculate and support the reporting of the **TPC-Energy Primary Metric** the following data must be collected.

- Total Runtime System Power during the **TPC Benchmark Standard** defined **Measurement Interval**(s).
  - Measured and logged at a maximum interval of 5 seconds
- Temperature readings
  - Measured and logged at a maximum interval of 2 minutes

5.3.2 Required Numerical Quantity Data

In order to calculate and support the reporting of the required numerical quantities the following data must be collected.

Total **Idle Power** after the **TPC Benchmark Standard** defined **Measurement Interval**(s) .

- All data processing must be completed
- Must start energy measurement within 30 minutes
- Must take measurement readings for a minimum duration of 10 minutes

- Reading must be taken and logged at a maximum interval of 5 seconds

5.3.3 Optional Secondary Metrics Data

In order to calculate and support the reporting of the optional **TPC-Energy Secondary Metrics** the following data must be collected.

1) Subsystem Energy Consumption for each subsystem during the TPC Benchmark Standard defined Measurement Interval(s).
   a. Logged at a maximum interval of 5 seconds
2) Subsystem Runtime Temperature(s) for the Subsystem which has the lowest ambient temperature and for each subsystem not collocated with other measured subsystems during the TPC Benchmark Standard defined Measurement Interval(s).
   a. Measured and logged at a maximum interval of 2 minutes
   b. Positioned at the air inlet with the lowest temperature
3) Sub-System Idle Energy Consumption for each subsystem after the TPC Benchmark Standard defined Measurement Interval(s)
   a. All data processing must be completed
   b. Must start measurement within 30 minutes
   c. Must have a continuous measurement interval of 10 minutes
   d. Logged at a maximum interval of 5 seconds

5.3.4 Additional Required Data

In order to support the **TPC-Energy Result** the following additional data must be collected for TPC-Certified Auditor review of the computations.

1) Individual power analyzer logs for each measurement.
2) Individual temperature logs for each measurement
3) Time synchronization for logs
4) Other data as required by the **Auditor**

CLAUSE 6 -- INSTRUMENTATION PROPERTIES

6.1 Devices

6.1.1 List of Approved Devices

Measurements for TPC-Energy require instrumentation to record power and temperature. These devices must be approved for use with the EMS and calibrated per requirements below. See Device List on the TPC website for a list of currently supported and compliant power analyzers and temperature sensors.

Additional devices may be submitted to the TPC for acceptance and addition to the Approved Devices. This request should be submitted to the TPC Administrator via e-mail.

6.1.2 Power Analyzer

The power analyzer is the device that will be connected or coupled to the power input of the **System Under Test** to collect power readings during the benchmark run. These devices vary in capability and features. They must meet a set of minimum requirements before an instrument is permitted to be used for TPC energy measurements.

To ensure comparability and repeatability of energy measurements, the TPC requires the following attributes for the power measurement device used during the benchmark. Please note that a power analyzer may meet the requirements when used in some power ranges but not in others, due to the dynamic nature of Power Analyzer Accuracy and Crest Factor.

6.1.2.1 Commercial Availability

The power analyzers, current and temperature probes used must be commercially available. They also must have accuracy specifications provided by the manufacturer.

6.1.2.2 Power Analyzer Measurements

The analyzer must report:

1) Real power (watts)
2) voltage
3) amperes
4) power factor

6.1.2.3 Probe Types

Inline resistive, flow-through or current clamp probes may be used by the power analyzers. Selection of probe types will vary the accuracy of the measurements.

6.1.2.4 Power Measurement Accuracy

Measurements of power must be with an average accuracy of not to exceed 2% for each set of power measurement data, for the ranges measured during the benchmark run. The accuracy of a particular measurement is affected by the combination of all analyzer and components uncertainties, for the ranges and frequency being measured. The accuracy of each measurement for a particular device must be calculated (see section 6.1.2.5 and 6.1.2.6) and is included in the calculation of the compensated value. (See section 6.1.2.7 for the calculation of the compensated value)

Each device's accuracy will be calculated as specified by the manufacturer for a particular reading and range.

If a power analyzer vendor provides a method to determine accuracy for the combination of devices (analyzer and probe), then the vendor's method must be used.

When a power analyzer vendor does not provide a method for determining the accuracy of multiple devices used in a measurement of a PMU, which have separate accuracy specifications and/or calculations, then the calculated accuracy of each device will be added to calculate the accuracy of the measurement.

6.1.2.5 Power Analyzer Accuracy calculation using device specifications.

Overall Accuracy is calculated using the vendor provided accuracy specifications for the devices. Typically this includes the accuracy of the Power Analyzer, the coupling device (inline, feed-thru, clamp-on), and range selection.

Example of default calculation for measuring 15KW:
An analyzer is used with a wattage range selection of 5-50W with a vendor-specified Power Analyzer Accuracy of +/- 0.05% of reading at this range. The combination of the analyzer and a clamp-on probe with an input/output ratio of 1500:1 with an accuracy of +/- 1.0% would have overall accuracy as follows:
0.05% + 1.0% = 1.05%

6.1.2.6 Power Analyzer Accuracy calculation using Vendor Specified methodology.

Overall Accuracy may be calculated using the vendors provided specifications and methodology of calculating the accuracy of a measurement using a particular coupling type. Typically this includes the accuracy of the Power Analyzer, the coupling device (inline, feed-thru, clamp-on), and range selection.

Example when specification is percent of reading (rdg):
An analyzer using in-line coupling, with a vendor-specified accuracy of +/- 0.1% of reading in a 20W-400W range, used in a test with an average wattage reading of 130W, would have overall accuracy as follows:

$$0.1\%*130W) = 0.13W$$

$$0.13W/130W = 0.1\% \text{ at } 130W$$

Example when specification is percent of range (rng)(the maximum of the selected range):
An analyzer using in-line coupling with a wattage range selection of 20-400W, with a vendor-specified accuracy of +/- 0.05% of range, used in a test with an average wattage reading of 130W, would have overall accuracy as follows:

$$(0.05\%*400W)=0.2W$$

$$0.2W/130W\ 0.15\% \text{ at } 130W$$

Example when specification is percent of reading (rdg) and percent of range (rng):
An analyzer using in-line coupling with a wattage range selection of 20-400W, with a vendor-specified accuracy of +/- 0.05% of range and a percent of reading accuracy of 0.1%, used in a test with an average wattage value of 130W, would have overall accuracy as follows:

$$((0.05\%*400W)+(0.1\%*130W))=0.33W$$

$$0.33W/130W = 0.25\% \text{ at } 130W$$

Example when specification is percent of reading (rdg) and a feed-thru coupling:
An analyzer using feed-thru coupling with a wattage range selection of 5-50W, with a vendor-specified Power Analyzer Accuracy of +/- 0.05% of reading, used in a test with a wattage value of 13KW, and a feed-thru probe with an accuracy of +/- 0.05% and 1500:1 input/output ratio would have overall accuracy as follows:

$$((0.05\%+0.05\%)*13{,}000W)=13.00W$$

$$13W/13{,}000W = 0.1\% \text{ at } 13KW$$

Example when specification is percent of reading (rdg) and a clamp-on coupling:
An analyzer using clamp-on coupling with a wattage range selection of 5-50W, with a vendor-specified Power Analyzer Accuracy of +/- 0.05% of reading, used in a test with a wattage value of 13KW, and a clamp-on probe with an accuracy of +/- 1.0% and 1500:1 input/output ratio would have overall accuracy as follows:

$$((0.05\%+1.0\%)*13{,}000W)=136.50W$$

$$136.5W/13{,}000W = 1.05\% \text{ at } 13KW$$

When an analyzer specification includes an accuracy +/- n-digits due to truncation, then to determine the accuracy, an additional factor of 4 times the unit value of the least significant digit must be added to the reading for the accuracy calculation.

6.1.2.7 **Compensated Value** Calculation

To compensate for the variations in accuracy of different power analyzers and probe types, the calculated overall accuracy of the device is used to adjust the power measurements by a factor that will ensure that the reported Result is conservative. The Accuracy Correction Factor is equal to 1 + the overall accuracy of the device. This is applied to the measured data, and is calculated as follows:

Compensated Value = reading * Accuracy Correction Factor

This calculation is performed on each measurement before combining, scaling, or averaging multiple measurements.

Comment: The intent of this is to allow the use of a wide variety of measurement devices and to pessimistically compensate for their varying accuracy characteristics.

6.1.2.8 Power Analyzer Crest Factor

The analyzer must provide a current crest factor of a minimum value of 3. For analyzers that do not specify the crest factor, the analyzer must be capable of measuring an amperage spike of at least 3 times the maximum RMS amperage measured during any sample of the benchmark test.

Examples:

A power analyzer which is set to a range of 10 amps, with a specified Crest Factor of 3 is able to integrate a spike of up to 30 amps.

If a Crest Factor is not specified for a power analyzer by its vendor, then the maximum amperage measured during the benchmark run must not exceed 33% of the maximum amperage of the selected range setting to allow for integration of a spike three times larger.

6.1.2.9 Power Analyzer Logging

The analyzer must have an interface that allows its measurements to be read by the EMS-PTD software. The Data Reading Interval supported by the analyzer must be able to communicate its reading of all required values in less than or equal to the Maximum Power Sample Period (5 seconds). The Data Reading Interval setting must be less than or equal to the internal Data Averaging Interval of the analyzer to insure that all time periods being measured by analyzer are also communicated to the EMS-PTD software (e.g. If the internal analyzer Data Averaging Interval is 2 seconds, then the Data Reading Interval must be set to value of 2 seconds or less).

6.1.3 **Temperature Sensors**

The Temperature Sensor is the device that is positioned in the flow of air into the system under test to collect temperature readings during the benchmark run. These devices must meet a set of minimum requirements before an instrument is permitted to be used for TPC temperature measurements.

Temperature must be measured no more than 100mm (approximately 4 inches) upwind of the main inlet for airflow to the equipment being benchmarked. If there are multiple inlet locations, a survey of temperatures should be taken, and the inlet with the lowest ambient temperature should be used to monitor temperature. Even for a configuration that includes several servers and/or storage units, a single temperature probe should be sufficient when all the subsystems are collocated. The **Test Sponsor** must take steps to ensure that they are measuring at the coolest inlet.

If a **Test Sponsor** finds that the temperature at the air inlet is less than **20 degrees** Celsius, steps must be taken to ensure that the **20-degrees** requirement is met.

To ensure comparability and repeatability of temperature measurements, the following attributes for the temperature measurement device(s) are required in the benchmark:

6.1.3.1 Temperature Sensor Logging

The sensor must have an interface that allows its measurements to be read by the benchmark harness. The manufacturer's specified reading rate supported by the sensor must be at least 1 sample per minute. Temperature must be measured on a regular basis throughout the measurement. The low temperature measured must be reported with the benchmark disclosure. The **Test Sponsor** is required to include a statement that they did not do anything to intentionally lower the temperature for any equipment inlet during the run of the measurement and that the reported temperature is measured at the air inlet(s) expected to have the lowest ambient temperature.

6.1.3.2 Temperature Accuracy

Measurements must be reported by the sensor with an overall accuracy of +/- 0.5 degrees Celsius or better for the ranges measured during the benchmark run.

6.1.3.3 Multiple Temperature Sensors Requirements

When components or subsystems of the SUT are not collocated, temperature readings must be taken at each location during the measurement interval(s).

Conditions that are likely to warrant multiple temperature measurements are as follows:

- The components or subsystems are physically located in a different location that has a different cooling air supply.
- The components or subsystems are physically located in a different area of the same location that has a different cooling air supply.
- Possible variations in temperature of the location of the components or subsystems make it difficult to ensure that choosing a single air inlet will be the lowest temperature for the duration of the measurements.

6.2 **Certification Testing**

6.2.1 **Power Analyzer Calibration**

The analyzer must be able to be calibrated by a standard traceable to NIST (U.S.A.) (http://nist.gov) or a counterpart national metrology institute in other countries. The analyzer must have been calibrated within the past year.

6.2.2 Acceptance Process for New Measurement Devices

6.2.2.1 Adding a new measurement device to the TPC power measurement framework includes three components:

1) Providing documentation that the device meets the requirements of Section 6.1.2.
2) Adding a new source code or parameter file to the EMSDevices module to allow the **EMS** controller software to control the device.
3) Performing tests with TPC Benchmarks to evaluate the actual behavior of the device.

6.2.2.2 Documentation to prove compliance with all required attributes must be provided. Publicly available documentation is preferred, but in cases where a device vendor does not wish to disclose information perceived as proprietary, the device vendor may request its documentation remain TPC Confidential.

6.3 Multiple Devices

There are several situations where use of multiple devices may be required to do the required energy measurements. These include measuring of subsystems for secondary metrics, gathering of Power Measurable Unit (PMU) data to allow for substitution, and gathering of data for subsets of the REC, where the data of the subset of the REC is scaled up to the full configuration.

6.3.1 Combining Data From Multiple Devices

The energy data may be gathered from multiple devices and combined by either combining data at the same points in time or by gathering the data in multiple runs and combining the totals. In order to facilitate the combination of data at the same points in time timestamps are required to be logged by the **EMScontroller.** The clocks used in logging timestamps must be within 5 seconds of each other for the duration of the measurement interval, and will be used to determine the measurement combination window.

6.3.2 Probe Types

Inline resistive, flow-through or current clamp probes may be used by the power analyzers. When data from different probe types are combined, the **Accuracy Correction Factor** for that probe type must be used in calculating the reported values for that measurement before that data is combined with the other measurement data.

6.3.3 Component Subset Measurement

Multiple power analyzers may be used to gather data on different subsets of the system in order to provide energy consumption for each subsystem. For instance, the database server, client systems and storage subsystems will have separate energy consumption values. The data may be gathered in multiple runs or by multiple devices in a single run. This data is collected in order to report **TPC-Energy Secondary Metrics**.

6.3.4 Measurement Granularity

Multiple power analyzers may be used to gather data on different **Power Measurable Unit** s (**PMU**) of the system in order to provide data on the energy used for the REC or subsystems of the REC. For instance, a single disk rack or a single client system may be identified as a **PMU** for purposes of **energy consumption extrapolation** or substitution

The data may be gathered in multiple runs or by multiple power analyzers in a single run or multiple analyzers in multiple runs.

CLAUSE 7 -- FULL DISCLOSURE REPORT

7.1 Introduction

Each TPC Benchmark Standard requires a **Full Disclosure Report** **(FDR)**. It is not intended for the requirements listed here to replace or eliminate any reporting requirements specified in the TPC Benchmark Standard or Pricing specifications. This section documents information that must also be disclosed if a **TPC-Energy** **Result** is reported as a part of a benchmark **Result**.

1) An Energy appendix must be included in the FDR in the same format required by the TPC-Benchmark Standard.
2) An Energy page must be included in the **Executive Summary** in the same format required by the TPC-Benchmark Standard.
3) If required by the **TPC Benchmark Standard**, an XML document ("ES.xml") with the same information as is in the Executive Summary must be included.
4) If required by the TPC Benchmark Standard, the Supporting Files consisting of the files listed in Clause **7.4** must be included. Requirements for the FDR file directory structure are described below.

If a **TPC-Energy** **Result** is reported as a part of a **Result**, an energy-related section of the **Full Disclosure Report** (FDR) is required:

Comment: The purpose of the FDR is to document how a benchmark **Result** was implemented and executed in sufficient detail so that the **Result** can be reproduced, given appropriate hardware and software products.

7.2 Executive Summary Requirements

The TPC Executive Summary must be included near the beginning of the **Report** as specified in the TPC Benchmark Standard. An example of the Executive Summary is presented in each TPC Benchmark Standard. The latest version of the required format is available from the TPC Administrator. If a **TPC-Energy** **Result** is included in the FDR, it must appear in two places in the Executive Summary:

- As a summary metric in the first page of the Executive Summary
- As a separate page appended to the Executive Summary pages.

7.2.1 First Page of the Executive Summary

7.2.1.1 The first page of the Executive Summary includes one or more lines that show the **TPC-Energy Primary Metric** of the benchmark:

- For energy-related measurements, the **TPC-Energy Primary Metric** for the particular TPC Benchmark Standard must be reported in a separate box in the proximity of the Primary Metrics in the Executive Summary of the **Result**, either by inserting an additional column or by adding a separate line (see Appendix B.)

7.2.1.2 Additional Page(s) of Executive Summary

Following the numerical quantities and Price Spreadsheet required by the benchmark, an energy summary must be included in the Executive Summary:

1) **TPC-Energy Primary Metric**: Reported Power per Unit of Work for the entire **Required Energy Configuration.**

2) **TPC-Energy Secondary Metrics:** If the **Sponsor** chooses not to disclose **Secondary Metrics**, a statement must be included to that effect. When reporting **Secondary Metrics,** each of the following must be included:

   a. Secondary metric for Database Server Subsystem

   b. Secondary metric for Application Server Subsystem

   c. Secondary metric for Storage Subsystem

   d. Secondary metric for Miscellaneous Subsystem

   Note: If a subsystem is not present in a benchmark configuration (for example, there is no Miscellaneous equipment, or, as is the case with the TPC-H Benchmark Standard, there is no Application Server), the value 'N/A' should be listed for that subsystem.

3) **TPC-Energy Numerical Quantities:**

   a. Average power of the **REC** in watts.

   Note: For benchmarks with a single measurement interval, this is the average total power for that interval. For benchmarks with more than one interval that contribute to the primary performance metric, this value is the average power for each interval, weighted by the time of that interval as a percent of the total measurement time.

   b. **Idle Power** of the REC in watts.

   c. Subsystems average power in watts, if secondary metrics are reported by the **Sponsor**.

   d. Subsystems Idle Power in watts, if secondary metrics are reported by the **Sponsor**.

   e. Subsystems percentage of the REC Average Power, if secondary metrics are reported by the **Sponsor**.

   f. Subsystems percentage of the REC Idle Power, if secondary metrics are reported by the **Sponsor**.

   g. When reporting Secondary Metrics, the Secondary Metrics and Numerical Quantities for each of the Subsystems must be reported in the form of a table. The Primary Metric and Numerical Quantities for the REC must also be included in the table. See examples in Appendix B

4) Declaration of any components of the **Priced Configuration** not part of the REC, with a reference to the FDR for additional details. (e.g. Spares used for maintenance need not be measured.)

5) Declaration of any components of the **REC** that were not measured as a part of the MEC, with a reference to the FDR for additional details. (e.g. Subset of like PMUs.)

6) Lowest measured Ambient Temperature.

7.3 Full Disclosure Report Requirements

Energy-related reporting will be included as a separate appendix of a benchmark **FDR**. The order and titles of the appendix sections in the **Report** and **Supporting Files** must correspond with the order and titles of sections from the TPC-Energy Standard Specification (i.e., this document). The intent is to make it as easy as possible for readers to compare and contrast material in different **Report**s.

7.3.1 TPC-Energy Clause 0 and Clause 1

Clause 0 and Clause 1 have no specific disclosure requirements.

7.3.2 **TPC-Energy Clause 2-related items (Methodology)**

7.3.2.1 The minimum ambient temperature must be disclosed.

7.3.2.2 The characteristics of the external electric power source must be disclosed. In particular, the voltage, frequency in Hertz, and phase information must be reported.

7.3.2.3 A statement is required that assures that nothing was done to alter the air-pressure in the measurement environment.

7.3.2.4 A description of where the temperature was measured and how it was determined that this was representative of the lowest ambient temperature is required.

7.3.2.5 If a method of cooling other than circulation of ambient air is employed in the **REC**, a statement describing this method must be included.

7.3.2.6 To be compliant with licenses associated with EMS, the following statement must be included in every FDR which contains a TPC-Energy Metric:

> "The power and temperature characteristics of the MEC were measured using TPC's Energy Measurement Software (EMS). This includes the EMS-PTD, a modified version of the SPEC PTDaemon, which is provided under license from the Standard Performance Evaluation Corporation (SPEC)."

7.3.3 **TPC-Energy Clause 3-related items (Metrics)**

7.3.3.1 Primary Metric

1) The normalized work (SUT Work Completed) derived from the **Performance Metric** (as described in Clause 3.2.1) must be disclosed
2) The computation for total energy used (REC Energy Consumption) for each measurement segment that contributes to a **Performance Metric** must be disclosed. If the energy of the entire **Priced Configuration** is not derived from direct measurements, the methods for deriving the energy for components which were not measured must be disclosed (See Clause 7.3.3.4).
3) The duration of each measurement that produces a **Performance Metric** must be disclosed.
4) The average power requirement for each measurement that produces one of these metrics.
5) The **TPC-Energy Primary Metric** must be disclosed, including the calculation that is used to derive it.

7.3.3.2 Secondary Metrics At Reported Performance

If the **TPC-Energy Secondary Metrics** are reported, the **components** of the **REC** which are included in each subsystem must be identified. This can be achieved with separate lists to be included in the **FDR** or with a specific designation in the price spreadsheet. Every **component** in the **REC** that consumes energy must be included in exactly one subsystem.

For each defined subsystem, the calculations defined for the **TPC-Energy Secondary Metrics** in Clause 3.3 must be reported, using the **Performance Metric** of the entire SUT and the energy consumption for each REC subsystem.

7.3.3.3 **Idle Power** reporting

1) The Idle Power measurement/calculation for the REC must be reported as numerical quantities.
2) If TPC-Energy Secondary Metrics are reported, then the Idle Power measurement/calculation for each subsystem must also be reported as numerical quantities.

3) The length of time between the conclusion of the performance measurement and the start of the idle measurement must be reported.

4) The duration of the idle measurement must be reported

5) A statement is required that assures that the system is in a state that is ready to run the Application(s) of the benchmark for the duration of the idle measurement.

7.3.3.4 Disclosure requirements when only part of the REC is measured for power.

If all PMU's of the **REC** are not measured for energy use, the **FDR** must include a description of which PMUs of REC were measured with a power analyzer. The FDR must disclose which PMUs of the **REC** were computed based on the energy measurements of similar PMUs. A diagram must be included that identifies the portions of the configuration which were measured for energy use and which were calculated. This diagram may be combined with other diagrams required by the **TPC Benchmark Standard.**

- The method used to determine which **PMUs** were measured must be disclosed.
- The power values for the each partial-REC measurement for duration of the performance and idle measurements must be disclosed.
- The calculation for the power requirements of the entire **REC** and, if applicable, each subsystem must be disclosed.

7.3.3.5 Disclosure requirements when component substitution is used.

If the **TPC Benchmark Standard** allows the **Priced Configuration** to differ from the **Measured Configuration**, the methods used to assign energy or power characteristics to the substitute components must be disclosed.

The method used to determine which **PMUs** were measured must be disclosed.

The power values for the each partial-REC measurement for duration of the performance and idle measurements must be disclosed.

7.3.4 TPC-Energy Clause 4-related items (Drivers /Controller)

7.3.4.1 A statement indicating the version of EMS used must be included in the FDR, including a statement that no alterations of this code were made for the benchmark, except as specified by Clause 7.3.4.3. This includes levels for the EMS-PTD Manager, EMS-PTD, EMS Report Generator, and EMS-controller.

7.3.4.2 Input parameters for the EMS software must be disclosed.

7.3.4.3 Any changes in the EMS components must be documented. Documentation must include a description of the issue, the reason the change was necessary for disclosure of the Result, and the changes made to resolve it. Any change to TPC-Provided Code must be included with the submission as a Supporting File.

7.3.5 TPC-Energy Clause 5-related items (Rules and Procedures)

Clause 5 disclosure requirements are included in the requirements listed for other clauses in this specification.

7.3.6 TPC-Energy Clause 6-related items (Instrumentation)

7.3.6.1 For each separate energy measurement (each subset measurement for each distinct measurement period), the following must be reported:

1) Analyzer used (make, model)

2) Date of certification of the analyzer (NIST or equivalent)

3) Range settings for Amperage, Voltage, and other settings for the measurement period

4) Specifications of any additional probes used in the energy measurement

5) The accuracy percentages used in the calculations and the source of those percentages

7.3.6.2 The make and model of the temperature sensor and/or probe must be disclosed.

7.3.6.3 The accuracy percentage for the temperature sensor and/or probe and the source of this information must be disclosed.

7.3.7 TPC-Energy Clause 7-related items

This sub-clause is included to retain consistent numbering between sub-clauses and their related TPC-Energy Specification clauses.

7.3.8 TPC-Energy Clause 8-related items

The **Auditor**'s **Attestation Letter**, which indicates the Auditor's opinion of compliance, is required to be included in the **FDR** by all **TPC Benchmark Standards**. When a **TPC-Energy** **Result** is reported, the **Auditor**'s **Attestation Letter** must also include a statement of compliance with the **TPC Energy Specification**.. See Clause 8.1.1.4 for additional information on the **Attestation Letter** requirements.

7.4 Supporting Files

The supporting files for the TPC-Energy Benchmark are required to be uploaded to the TPC Web Site as part of the benchmark submission process. These files are in addition to the required Executive Summary and Full Disclosure Report. The file format is specified for each required file type in the list below.

7.4.1 Energy Measurement Log Files

The log files input to and output by the EMS-Report Generator for all data used in the calculations of the REC Energy Consumption are required to be uploaded as part of a TPC-Energy Benchmark publication. The Logs will be in XML format including the following fields.

1) Device Type: <VM1000> <Temp@lert> <wm210>
2) Device Setting Poll-Rate <# of milliseconds between polls>
3) Changes to Device settings for the MaximumRange <watts>
4) Changes to Device settings for the MaximumVoltage <volts>
5) Changes to Device settings for the MaximumCurrent <amperes>
6) Data Amps <amperes>
7) Data Voltage <volts>
8) Data Frequency <Hertz>
9) Data Power <watts>
10) Data PowerFactor <ratio 0.0 to 1.0>
11) Data Temperature <degrees in Celsius>

7.4.2 Energy Measurement Controller Log Files

The log files output by the EMS-Controller for all data used in the calculations of the REC Energy Consumption are required to be uploaded as part of a TPC-Energy Benchmark publication. The Logs will be in the format specified by the EMS-Controller module.

7.4.3 **Energy Measurement Configuration Files**

The configuration files used by the EMS for all Performance Runs used in the calculations of the REC Energy Consumption are required to be uploaded as part of a TPC-Energy Benchmark publication. The Configuration files will be in the format specified by the EMS modules.

Note that some brand names are included in the following lists, for illustration purposes. This is not intended to indicate that only the brands listed are valid for TPC-Energy measurements.

7.4.3.1 The following information for each Power Analyzer Device is required to be disclosed in the FDR:

1) Device Type: <PM1000> <wt210>
2) Server Name: <Name of server connected to device>
3) Port Name: <Name and/or number of port used to communicate to device>
4) Device Setting PollRate <# of milliseconds between polls>
5) DeviceSetting MaximumRange <watts>
6) DeviceSetting MaximumVoltage <volts>
7) DeviceSetting MaximumCurrent <amperes>
8) DeviceSetting ProbeType <String with probe model number>
9) DeviceSetting ProbeRatio <String with probe current reduction ratio>

7.4.3.2 The following information for each Temperature Sensor Device is required to be disclosed in the FDR:

1) Device Type: <Temp@lert>
2) Server Name: <Name of server connected to device>
3) Port Name: <Name and/or number of port used to communicate to device>
4) Device Setting PollRate <# of milliseconds between polls>

7.4.4 **Supporting Files Index**

An index for all the uploaded **Supporting Files** must be provided in the **Report**. The **Supporting Files** index is presented in a tabular format where the columns specify the following:

- The first column denotes the clause in the TPC Specification
- The second column provides a short description of the file contents
- The third column contains the path name for the file starting at the Supporting Files directory.

If there are no **Supporting Files** provided then the description column must indicate that there is no supporting file and the path name column must be left blank.

CLAUSE 8 -- INDEPENDENT AUDIT

8.1 General Rules

8.1.1 Audit Requirements

8.1.1.1 Prior to its publication, a TPC Benchmark result disclosing energy metrics as defined in this TPC-Energy specification, must be reviewed by an independent, TPC-Certified **Auditor** for compliance with the additional audit requirements in the **TPC-Energy Specification**. The additional TPC-Energy audit requirements may be accomplished as extension of the TPC Benchmark Standard audit. These requirements may also be audited separately by the same or a different **TPC-Certified Auditor**, providing a separate attestation letter.

8.1.1.2 A generic audit checklist is provided as part of this specification. The Auditor may choose to provide the **Sponsor** with additional details on the TPC-Energy audit process.

8.1.1.3 The generic audit checklist specifies the audit requirements that should be checked to ensure a TPC-Energy **Result** is compliant with the **TPC-Energy Specification**. The TPC-Energy requirements are also required to be **reported** in the **FDR**. Not only should the TPC-Energy requirements be checked for accuracy, but the **Auditor** must ensure that the **FDR** accurately reflects the audited TPC-Energy **Result**. For example, if the audit checklist indicates to "verify that a power analyzer is calibrated as specified", the calibration must be verified to be accurate and verified to be the same calibration date that is **reported** in the **FDR** as specified by Clause.7.3.6

8.1.1.4 The **Auditor's** opinion regarding the compliance of a **Result** must be documented in an **Attestation Letter** delivered directly to the **Sponsor**. Upon request, and after approval from the **Sponsor**, a detailed audit report shall be produced by the **Auditor**.

8.1.1.5 The Attestation Letter must include:

1) Verification that the power analyzers used are correctly calibrated and meet the requirements of the TPC-Energy Specification
2) An opinion that the energy measurements were compliant with the requirements of the TPC-Energy Specification
3) For calculated energy values, a statement identifying how PMUs were selected for measurement and an opinion that they are representative of any similar PMUs for which energy use is calculated
4) Verification that the calculations for the TPC-Energy Primary Metric and for applicable TPC-Energy Secondary Metrics and Idle Power values were completed correctly
5) Verification that the EMS energy measurement control tools that were used are compliant with the requirements of the TPC-Energy Specification.
6) An opinion that the overall information presented in the Executive Summary and the Energy Appendix of the FDR accurately reflects the energy consumption of the Priced Configuration.

8.1.1.6 The scope of the audit is limited to the functions defined in this specification in addition to the functions defined in a particular TPC Benchmark Standard.

8.1.1.7 A **Sponsor** cannot demonstrate compliance of a new TPC-Energy **Result** by referring to the **Attestation Letter** of another **Result**. All **TPC-Energy Result**s must meet the TPC-Energy Specification requirements on the actual REC being priced.

8.2 **Audit Check List**

8.2.1 **Required information from the Sponsor**

The auditor may require the **Sponsor** to provide any information that will ensure a confident attestation of compliance with the TPC-Energy Specification. At a minimum, the following list must be provided to the auditor from the **Sponsor**:

1) Individual power analyzer logs (PTDM logs) and output from RGen for each measurement
2) Individual Temperature logs (PTDM Logs) and output from Rgen for each measurement
3) Time synchronization logs
4) A letter indicating:
    a. Components used in the REC are representative of a configuration that would be installed in a customer location
    b. No artificial means were employed to select optimal components beyond what would be done in a normal manufacturing process to fulfill a customer order
    c. The **Sponsor** measured the temperature at the air inlet(s) expected to have the lowest ambient temperature.

8.2.2 **Auditing EMS**

8.2.2.1 Verify that the version of **EMS** used is compliant with the version of the TPC-Energy specification used for publication (see Clause 4.4).

8.2.2.2 If the **Test Sponsor** modified **EMS** in response to a formal waiver issued by the TPC, verify that the changes fall under the scope of the waiver (see Clause 4.4.5.1).

8.2.2.3 If the **Test Sponsor** modified **EMS** outside of an existing TPC waiver, review the changes to verify that it was done for the exclusive purpose of correcting a newly discovered error in **EMS** (see Clause 4.4.4).

8.2.2.4 Verify that the version of **EMS-PTD MANAGER** used is compliant with the current version of the TPC-Energy specification

8.2.2.5 Verify that modifications or extensions made by the **Sponsor** to **EMS-PTD MANAGER** do not compromise the values for the data generated by **EMS-PTD MANAGER** (see Clause 4.4.4).

8.2.2.6 Verify the Calibration Date of all Power Analyzers used in measurements.

8.2.2.7 Verify that the restrictions on operator interventions are met.

8.2.2.8 Verify that the system clocks synchronization delta is recorded and complies with Clause 4.3.4.1

8.2.3 **Auditing the Execution Rules and Metrics**

The **Auditor** must verify that all TPC-Energy execution rules have been followed by the **Test Sponsor**. The **Auditor** may require the review of any and all output of the benchmark environment. The **Auditor** can require additional verification not specified in the TPC-Energy Specification to ensure the validity of the Benchmark Execution Rules and the resulting **TPC-Energy Metric**.

8.2.3.1 If **TPC-Energy Secondary Metrics** are reported, verify that at least 90% of the workload associated with each subsystem is performed by the PMUs reported for the subsystem metric, per clause 3.3.1.

8.2.3.2 Verify that Idle Power was measured at a time when the SUT was ready to accept work, per clauses 3.3.3 - 3.3.5.

8.2.3.3 If one or more UPS is/are included in the REC, verify that the UPS is not providing supplementary power to the REC during the measurement period. If secondary metrics are reported, verify that no UPS connects to multiple subsystems.

8.2.3.4 Verify that the temperature readings were taken at the air inlet(s) which is likely to have the lowest ambient temperature. It is the **Sponsor**'s responsibility to select this location. The auditor can require additional temperature readings be taken at other air inlets based upon the system configuration and component distribution of the REC (See section **Error! Reference source not found.**).

8.2.4 Auditing the TPC-Energy Measurements

The **Auditor** must verify that the implementation of the **energy measurements** demonstrates compliance with the requirements of the **TPC-Energy Specification**. The **Auditor** may require the review of the source code implementing these measurements and any associated scripts or programs. The **Auditor** can require additional verification not specified in the **TPC-Energy Specification** to ensure the validity of the **measurements**.

8.2.4.1 Verify that the TPC-Energy Primary Metric is correctly computed from measured and extrapolated data.

8.2.4.2 If reported, verify that the TPC-Energy **secondary metrics are** correctly computed from measured and extrapolated data.

8.2.4.3 If any component of the **REC** is extrapolated from information other than direct measurement of the component, verify that the extrapolations comply with the procedures documented in Clause 3.6.2. Identify the method used to select a subset of PMUs to measure, if applicable, and verify that the selected PMUs were correctly used in the extrapolations.

Auditing the **FDR**

8.2.4.4 Verify that the **Executive Summary** is accurate and complies with the reporting requirements as specified in 7.3.

8.2.4.5 Verify that the **Report** complies with the reporting requirements as specified by Clause 7.3.

8.2.4.6 Verify that the **Supporting Files** comply with the reporting requirements as specified by Clause 7.4.

8.2.4.7 Verify that the measured and non-measured components of the Priced Configuration are correctly identified and that sufficient information is provided to validate the extrapolation of energy requirements for any non-measured component.

8.2.4.8 Verify that modifications or extensions made by the **Sponsor** to **EMS** Software are documented in sufficient detail in the **Report** and that the code for the modification or extension is **reported** in the **Supporting Files** (see Clause 7.3.4.3).

8.2.4.9 A complete review of the **Report** by the **Auditor**, beyond the sections listed above, may be requested by the **Sponsor**, but is not required.

Appendix A. **EMS DOCUMENTATION**

A.1 Overview

EMS is a TPC provided software package. It is designed to facilitate the implementation of TPC-Energy. This appendix provides information on how a **Test Sponsor** is to use the features and functionality of EMS. The definitions, descriptions, constraints and regulations governing the use of EMS are captured in Clause 4 -- .

Comment: Some of the following sections assume the reader has a good understanding of object-oriented design and programming techniques using ANSI C++.

A.2 EMS Directory

A.2.1 EMS Directory Hierarchy.

EMS is distributed in a single directory hierarchy. The following diagram shows the overall EMS directory hierarchy.

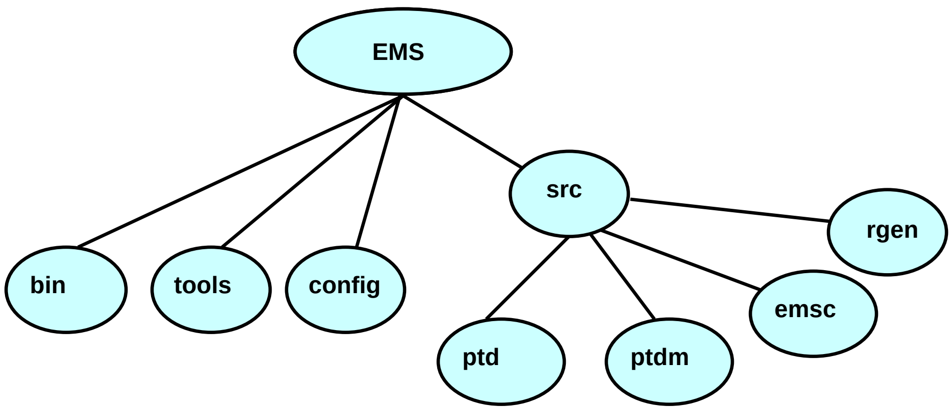

Figure 2 - Hierarchy of EMS Directory

- bin – default target directory for executable binary files for various operating systems
- tools - contains additional software and scripts for ease of benchmarking but not required by the benchmark specification
- src – contains source files and project files
- src/ptd – contains TPC-developed source files for the Power Temperature Daemon (PTD)
- src/ptdm – contains source files for the PTD Manager (PTDM)
- src/emsc – contains source files for the EMS Controller (EMSC)
- src/rgen – contains source files for the Report Generator (RGEN)

Note: Not all source code is publicly available.

A.3 EMSProjectFiles

A.3.1 EMSProjectFiles Directory

EMSProjectFiles are located in the EMS/src directory and its appropriate subdirectories. These files can be used to facilitate building EMS components in various environments.

- Windows

A set of Visual Studio 2003 files are provided. EMS.sln is the top level solution file and brings in all of the necessary .prj files.

- Unix, Linux, Solaris, AIX, HPuX, etc.

  A make file (makefile) is provided to facilitate building the EMS components using a make utility. The makefile is known to work with GNU make, but other versions of make may require some editing of the makefile.

A.4 EMSConfigFile

A.4.1 **EMSConfigFile** Directory.

The EMSConfigFile is located in the EMS/config directory. This file is an XML formatted file containing the configuration information for the measurement components. The file is used by the **EMS-Controller** to setup and record energy and temperature data. It is also used by the Report Generator in producing the reportable metrics.

Appendix B. EXECUTIVE SUMMARY

B.1 Sample Layouts for TPC-E

Heading for page 1 of TPC-E Executive Summary with a TPC-Energy Primary Metric (Fonts should be as specified in the TPC-E Benchmark Standard specification.):

Sponsor		System Configuration		TPC-E xx.y.z TPCPricing xx.y.z TPC-Energy xx.y.z **Report Date** January XX, XXXX **Revised Date** May XX, XXXX
TPC-E Throughput XX,XXX tpsE	**Price/Performance** $X.XX USD per tpsE	**Availability Date** August XX,XXXX	**Total System Cost** $XXX,XXX	**TPC-Energy Metric** XX.XX Watts/tpsE

Figure 3 - Sample TPC-E Executive Summary

Following the rest of the Executive Summary, as specified in the TPC-E Benchmark Standard specification, the following Energy Summary page is required if Secondary Metrics are reported:

System Configuration		**Energy Summary**		TPC-E xx.y.z TPCPricing xx.y.z TPC-Energy xx.y.z Report Date January XX, XXXX Revised Date May XX, XXXX
TPC-E Throughput XX,XXX tpsE	**Price/Performance** $X.XX USD per tpsE	**Availability Date** August XX,XXXX	**Total System Cost** $XXX,XXX	TPC-Energy Metric XX.XX Watts/tpsE

Numerical Quantities For Reported Energy Configuration:

REC Idle Power: xxx Watts

Average Power of REC: xxx Watts

Subsystem Reporting:

	Secondary Metrics	Additional Numerical Quantities:			
	Watts / tpsE	Full Load Avg.Watts	Full Load % of Rec	Idle Avg. Watts	Idle % of Rec
Database Server	xxx.xx	xxx.xx	xx%	xxx.xx	xx%
Storage	xxx.xx	xxx.xx	xx%	xxx.xx	xx%
Application Server	xxx.xx	xxx.xx	xx%	xxx.xx	xx%
Miscellaneous	xxx.xx	xxx.xx	xx%	xxx.xx	xx%
Total REC	xxx.xx	xxx.xx	100%	xxx.xx	100%

Lowest ambient temperature at air inlet: xx.x Degrees Celsius

Items in Priced Configuration not in the Reported Energy Configuration
[list] or reference to identifying marking in the price spreadsheet

Items in the Reported Energy Configuration not in the Measured Energy Configuration
[list] or reference to identifying marking in the price spreadsheet

Figure 4 - Example TPC-E Executive Summary Energy Page

When subsystem metrics are not reported, the table below "Subsystem Reporting" must be replaced with the phrase:

"Secondary (subsystem) Metrics are not reported. Comparisons to other TPC-Energy Results must not reference subsystem energy information."

B.2 Sample Layouts for TPC-C

Heading for page 1 of TPC-C Executive Summary with a TPC-Energy Primary Metric (Fonts should be as specified in the TPC-C Benchmark Standard specification.):

Sponsor		System Configuration		TPC-C xx.y.z TPCPricing xx.y.z TPC-Energy xx.y.z **Report Date** January XX, XXXX **Revised Date** May XX, XXXX
Total System Cost $XX,XXX USD	**TPC-C Throughput** XX,XXX tpmC	**Price/Performance** $X.XX USD/tpmC	**Avaiability Date** [month] XX, 20XX	**TPC-Energy Metric** XX.XX Watts/KtpmC

Figure 5 - Sample TPC-C Executive Summary

Following the rest of the Executive Summary, as specified in the TPC-C Benchmark Standard specification, the following Energy Summary page is required if Secondary Metrics are reported:

System Configuration		**Energy Summary**		TPC-C xx.y.z TPCPricing xx.y.z TPC-Energy xx.y.z Report Date January XX, XXXX Revised Date May XX, XXXX
Total System Cost $XX,XXX USD	**TPC-C Throughput** XX,XXX tpmC	**Price/Performance** $X.XX USD/tpmC	**Avaiability Date** [month] XX, 20XX	TPC-Energy Metric XX.XX Watts/KtpmC

Numerical Quantities For Reported Energy Configuration:

REC Idle Power: xxx Watts

Average Power of REC: xxx Watts

Subsystem Reporting:

	Secondary Metrics	Additional Numerical Quantities:			
	Watts / KtpmC	Full Load Avg.Watts	Full Load % of Rec	Idle Avg. Watts	Idle % of Rec
Database Server	**xxx.xx**	xxx.xx	xx%	xxx.xx	xx%
Storage	**xxx.xx**	xxx.xx	xx%	xxx.xx	xx%
Application Server	**xxx.xx**	xxx.xx	xx%	xxx.xx	xx%
Miscellaneous	**xxx.xx**	xxx.xx	xx%	xxx.xx	xx%
Total REC	**xxx.xx**	xxx.xx	100%	xxx.xx	100%

Lowest ambient temperature at air inlet: xx.x Degrees Celsius

Items in Priced Configuration not in the Reported Energy Configuration

[list] or reference to identifying marking in the price spreadsheet

Items in the Reported Energy Configuration not in the Measured Energy Configuration

[list] or reference to identifying marking in the price spreadsheet

Figure 6- Sample TPC-C Executive Summary Energy Page

When subsystem metrics are not reported, the table below "Subsystem Reporting" must be replaced with the phrase:

"Secondary (subsystem) Metrics are not reported. Comparisons to other TPC-Energy Results must not reference subsystem energy information."

B.3 Sample Layouts for TPC-H

Heading for page 1 of TPC-H Executive Summary with a TPC-Energy Primary Metric (Fonts should be as specified in the TPC-H Benchmark Standard specification.):

My Logo	My Server	TPC-H xx.y.z TPC-Energy xx.y.z **Report Date** January XX, XXXX

Total System Cost	**Composite Query per Hour Metric**	**Price/Performance**	**TPC-Energy Metric**
$XXX,XXX USD	QphH@xxxGB	$/QphH@xxxGB	Watts/KqphH@xxxGB

Database Size	**Database Manager**	**Operating System**	**Other Software**	**Availability Date**
xxxGB	My DB	My OS		August XX,XXXX

Figure 7 - Sample TPC-H Executive Summary

Following the rest of the Executive Summary, as specified in the TPC-H Benchmark Standard specification, the following Energy Summary page is required if Secondary Metrics are reported:

My Server	**Energy Summary**	TPC-H xx.y.z TPC-Energy xx.y.z **Report Date** January XX, XXXX

Total System Cost	**Composite Query per Hour Metric**	**Price/Performance**	**TPC-Energy Metric**
$XXX,XXX USD	QphH@xxxGB	$/QphH@xxxGB	Watts/KQphH@xxxGB

Database Size	**Database Manager**	**Operating System**	**Other Software**	**Availability Date**
xxxGB	My DB	My OS		August XX,XXXX

Numerical Quantities For Reported Energy Configuration:

REC Idle Power: xxx Watts

Average Power of REC: xxx Watts

Subsystem Reporting:

	Secondary Metrics	Additional Numerical Quantities:			
	Watts / kQphH@xxxGB	Avg.Watts	Full Load % of Rec	Idle Avg. Watts	Idle % of Rec
Database Server	xxx.xx	xxx.xx	xx%	xxx.xx	xx%
Storage	xxx.xx	xxx.xx	xx%	xxx.xx	xx%
Application Server	xxx.xx	xxx.xx	xx%	xxx.xx	xx%
Miscellaneous	xxx.xx	xxx.xx	xx%	xxx.xx	xx%
Total REC	xxx.xx	xxx.xx	100%	xxx.xx	100%

Lowest ambient temperature at air inlet: xx.x Degrees Celsius

Items in Priced Configuration not in the Reported Energy Configuration

[list] or reference to identifying marking in the price spreadsheet

Items in the Reported Energy Configuration not in the Measured Energy Configuration

[list] or reference to identifying marking in the price spreadsheet

Figure 8 - Sample TPC-H Executive Summary Energy Page

When subsystem metrics are not reported, the table below “Subsystem Reporting” must be replaced with the phrase:

“Secondary (subsystem) Metrics are not reported. Comparisons to other TPC-Energy Results must not reference subsystem energy information.”