Using PowerCfg to Evaluate System Energy Efficiency

March 26, 2010

Abstract

This paper provides information about new functionality within the PowerCfg utility for evaluating system energy efficiency for the Windows® family of operating systems. It provides guidelines for system manufacturers to take advantage of this new PowerCfg functionality before shipping a new system model to customers. Similarly, IT professionals can use these PowerCfg enhancements to diagnose and resolve end-user problems with portable computer battery life and desktop energy efficiency.

In addition to power policy configuration, PowerCfg also enables system manufacturers to inspect a Windows platform for common energy efficiency problems. Many individual energy efficiency problems can be detected, including inefficient power policy settings, USB device selective suspend issues, and platform firmware problems that relate to processor power management capabilities. This paper describes how to use PowerCfg to evaluate system energy efficiency and details the energy efficiency problems that might be detected.

This Information applies to the Windows 7 operating system.

References and resources discussed here are listed at the end of this paper.

For the latest information, see:   
 <http://www.microsoft.com/whdc/system/pnppwr/powermgmt/PowerCfg.mspx>

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Document History

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Date | Change |  |  |  |
| March 26, 2010 | Added information that the energy-report.html file cannot be opened by Internet Explorer if it’s located in C:\Windows\System32. | | | |
| January 15, 2010 | Added reference to “Processor Power Management in Windows 7 and Windows Server 2008 R2.” | | | |
| March 12, 2009 | First publication | | | |

Contents

[Introduction 3](#_Toc257364702)

[Using PowerCfg to Evaluate Energy Efficiency 3](#_Toc257364703)

[Performing an Energy Efficiency Analysis 4](#_Toc257364704)

[Viewing the Analysis Results 5](#_Toc257364705)

[Problem Categories 5](#_Toc257364706)

[Fields 6](#_Toc257364707)

[Understanding Energy Efficiency Problems 7](#_Toc257364708)

[Power Policy 7](#_Toc257364709)

[Platform Timer Resolution 9](#_Toc257364710)

[System Availability Requests 10](#_Toc257364711)

[USB Selective Suspend 11](#_Toc257364712)

[CPU Utilization 12](#_Toc257364713)

[Battery 13](#_Toc257364714)

[Platform Power Management 14](#_Toc257364715)

[Processor Power Management 16](#_Toc257364716)

[Advanced PowerCfg Techniques 19](#_Toc257364717)

[PowerCfg -ENERGY Parameters 19](#_Toc257364718)

[Reviewing Trace Data with the Windows Performance Toolkit 21](#_Toc257364719)

[Troubleshooting the PowerCfg -ENERGY Command 21](#_Toc257364720)

[Multiple NT Kernel Logger Consumers 21](#_Toc257364721)

[Unexpected Termination of PowerCfg 21](#_Toc257364722)

[Conclusion 22](#_Toc257364723)

[Resources 22](#_Toc257364724)

# Introduction

To achieve maximum energy efficiency on a Windows® platform, all system components—including hardware, firmware, device drivers, applications, and services—must work together. If any single component on the system malfunctions with respect to power management, the energy efficiency of the entire system decreases. For example, a single USB device that does not enter the suspend state can increase system power consumption by up to 25 percent. Similarly, an application might incorrectly request that the display remain on, which prevents power savings when the user is not interacting with the system.

In Windows 7, the Windows PowerCfg utility is enhanced to detect many common energy efficiency problems, such as ineffective use of suspend by USB devices, excessive processor utilization, increased timer resolution, inefficient power policy settings, and battery capacity degradation. PowerCfg can help the following groups identify the cause of system energy efficiency problems:

* System manufacturers can run PowerCfg on each new model of computer system to verify that no severe energy efficiency problems exist before they ship it to customers.
* IT professionals can use the new PowerCfg capabilities as part of system validation or to provide support to users when they encounter battery life or power consumption issues.
* Software developers can use the new PowerCfg capabilities to validate the effect of their applications on the overall system energy efficiency, especially when the applications are background processes.
* Power users can use PowerCfg to diagnose energy efficiency problems on their own systems.

This paper will help you use PowerCfg to detect energy efficiency problems, to understand the analysis of the problems that PowerCfg detects, and to take actions to resolve the problems if possible. Note that PowerCfg is also used for power policy configuration.

For more information about how to optimize platforms for better energy efficiency, see “Optimizing Windows Vista Platforms for Energy Efficiency” and ”Mobile Battery Solutions Guide for Windows Vista” on the WHDC Web site. For more information about power policy configuration, see ”Power Policy Configuration and Deployment in Windows,” which is also on WHDC.

# Using PowerCfg to Evaluate Energy Efficiency

In Windows 7, PowerCfg supports a new command-line option, **‑ENERGY**, that you can use to analyze the energy efficiency of the platform. You must perform an energy efficiency analysis when the system is idle, with no applications open, and at least 10 minutes after the operating system has last been started. After PowerCfg completes the analysis, the number of energy efficiency problems appears in the command window. PowerCfg also generates an HTML-formatted report that contains details about each problem that it detected.

## Performing an Energy Efficiency Analysis

To perform an energy efficiency analysis, open an elevated command window and run PowerCfg with the **‑ENERGY** option, as shown in the following example:

C:/Windows/system32>powercfg –energy

Enabling tracing for 60 seconds...

Observing system behavior...

Analyzing trace data...

Analysis complete.

Energy efficiency problems were found.

3 Errors

5 Warnings

13 Informational

See C:/Windows/system32/energy-report.html for more details.

If you specify the ‑**ENERGY** option with no other parameters, the analysis runs for 60 seconds.

You must not interact with the system while the energy efficiency analysis is being performed. During the analysis, PowerCfg monitors several system instrumentation points that are sensitive to user activity. For example, the processor utilization data for system idle conditions is inaccurate if you start or interact with an application during the analysis. When the analysis is complete, the “Analysis complete” message appears. Then you can resume interacting with the system.

After PowerCfg completes the analysis, it displays the number of energy efficiency problems that were detected. PowerCfg then creates an HTML-formatted file in the current directory of the command window that is named *energy-report.html*. This file contains a report that includes additional details about the energy efficiency problems that PowerCfg detected during the analysis.

**Note:** You should consider the location of the energy efficiency report before you attempt to view it with Internet Explorer. By default, PowerCfg creates the file in the current directory of the command window in which PowerCfg runs. For example, if you run PowerCfg from the C:\Windows\System32 directory as shown in the preceding example, the file is created in that same directory. When User Access Control (UAC) is enabled, C:\Windows\System32 is considered a high-integrity resource. Therefore, if the energy efficiency report is located in this directory, Internet Explorer might not be able to open it for security reasons. For best results, we recommend that you do one of the following before you attempt to view the energy efficiency report:

* Copy or move the energy efficiency report from the C:\Windows\System32 directory to a directory that is configured to a lower integrity level, such as a document directory or the desktop.
* When you run PowerCfg, use the ‑**OUTPUT** option to specify a lower integrity-level directory for the energy efficiency report.
* Change the current directory of the command window to a lower integrity-level directory before you run PowerCfg.

## Viewing the Analysis Results

The beginning of the report contains a system information section. This section contains basic information about the platform on which the analysis was run, such as the computer name, system manufacturer, and BIOS information, as shown in Figure 1.

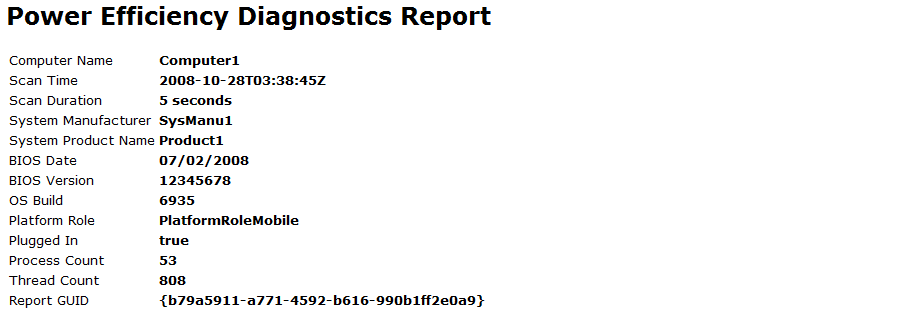


Figure 1. System information section in the energy efficiency analysis report

### Problem Categories

The main body of the report contains the analysis results. PowerCfg checks all potential sources of energy efficiency problems and categorizes the results of the analysis based on each problem's effect on the overall system energy efficiency. A detected problem is placed in one of the following categories:

* Error
* Warning
* Information

#### Error

If a problem is classified as an error, it means that the problem has a severe effect on the platform power consumption and/or battery life. Typically, problems that are classified as errors affect portable computer battery life or platform power consumption by more than 15 percent.

For example, the following detected problems would be classified as errors:

* The display idle time‑out is disabled.
* A USB device did not enter the suspend state during the analysis.

All errors in an energy efficiency analysis report appear with a red background, as shown in Figure 2.

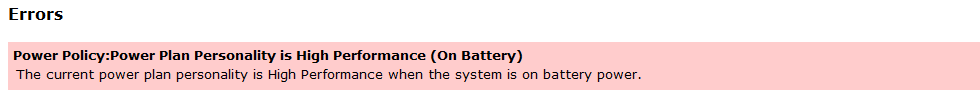


Figure 2. An error in the energy efficiency analysis report

#### Warning

If a problem is classified as a warning, it means that the problem has a moderate effect on the platform power consumption and/or battery life. Typically, problems that are classified as warnings affect portable computer battery life or platform power consumption by less than 15 percent.

For example, the following detected problems would be classified as warnings:

* The total processor utilization was less than 4 percent, but greater than 2 percent.
* The Display Idle Time‑out feature was enabled, but the time‑out was set to a value that was greater than 10 minutes for when the system is plugged in.

All warnings in an energy efficiency analysis report appear with a yellow background, as shown in Figure 3.

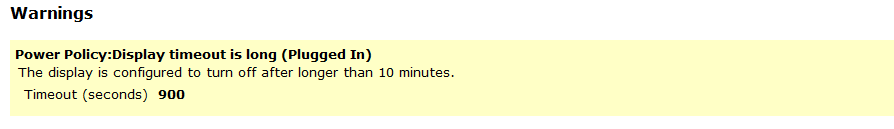


Figure 3. A warning in the energy efficiency analysis report

#### Information

The rest of the contents of an energy efficiency analysis report is informational data. Information items do not indicate energy efficiency problems. They are in the report to help identify the system or the system components that were inspected for energy efficiency problems.

All information items that are included in an energy efficiency analysis report appear at the end of the report with a white background, as shown in Figure 4.

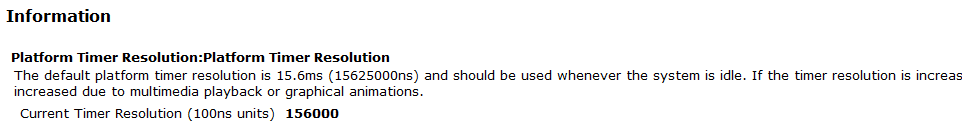


Figure 4. An information item in the energy efficiency analysis report

### Fields

Each item in the energy efficiency analysis report includes the following three fields that describe the potential energy efficiency problem:

* Class

A categorization of energy efficiency problems into the following classes:

* Power policy
* Platform timer resolution
* System availability request
* USB suspend
* CPU utilization
* Battery
* Platform power management capabilities
* Processor power management capabilities
* Problem

A brief description of the problem, such as “Power Plan Personality is High Performance (On Battery).”

* Detailed Description

A detailed description of the problem, such as “The current power plan personality is High Performance when the system is on battery power.”

Figure 5 shows how these three fields appear in a report item:

**Class Problem Detailed Description**

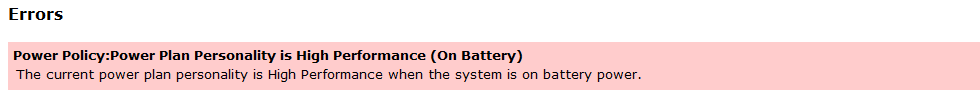


Figure 5. Item fields in an energy efficiency analysis report

# Understanding Energy Efficiency Problems

The problems that are identified in an energy efficiency analysis report could be related to power policies, application behaviors, firmware, drivers, or hardware. The following sections provide additional information about the methods and criteria that are used to analyze a system for energy efficiency problems, as well as possible suggestions to resolve problems that are detected. The information in this section is organized by class of energy efficiency problem.

## Power Policy

One of the most common energy efficiency problems on portable and desktop computers is inefficient power policy settings. The power policy settings might have been set incorrectly by the platform vendor when the system was manufactured or by the end user when the user tried to resolve an unrelated problem.

PowerCfg analyzes many power policy settings and logs errors, warnings, or information items in the energy efficiency analysis report, depending on the current values for the power policy settings:

* Errors are typically logged when a power-saving feature is disabled. For example, an error is logged if the display idle time‑out is set to 0 (disabled).
* Warnings are typically logged when a given power policy setting is set to a value that is out of bounds for power savings behavior. For example, a warning is logged if the display idle timeout is greater than 15 minutes when the system is plugged in.
* Information items are logged for common power policy settings, such as the current power plan and the personality of the current power plan.

For portable computers, both the **Plugged in** and **On battery** values for each power policy setting are inspected. If an energy efficiency problem is detected for both values, separate items are logged in the report, one for the **Plugged in** value and one for the **On battery** value. For desktop computers, only the **Plugged in** values are inspected.

Power policy problems can be resolved by changing the current power policy settings in the Control Panel Power Optionsapplication or by using PowerCfg in an elevated command window. Note that end users cannot change any power policy settings that IT professionals enforce by using Group Policy.

Table 1 provides a summary of the power policy items that PowerCfg analyzes. For each item that is analyzed, the description indicates how PowerCfg determines whether it is an error, a warning, or information.

Table 1. Power Policy Items that PowerCfg Analyzes

|  |  |
| --- | --- |
| Item analyzed | Description |
| Active power plan | Always logged as information. |
| Power plan personality (On battery) | Logged as an error if the personality of the current power plan is High Performance.  Otherwise, logged as information. |
| Power plan personality (Plugged in) | Logged as an error if the personality of the current power plan is High Performance.  Otherwise, logged as information. |
| Display time‑out (On battery) | Logged as an error if the display time‑out (On battery) is disabled.  Logged as a warning if the display time‑out (On battery) is set to a value that is greater than 5 minutes. |
| Display time‑out (Plugged in) | Logged as an error if the display time‑out (Plugged in) is disabled.  Logged as a warning if the display time‑out (Plugged in) is set to a value that is greater than 10 minutes. |
| Display dim time‑out (On battery) | Logged as an error if the display dim time‑out (On battery) is disabled.  Logged as a warning if the display time‑out (On battery) is set to a value that is greater than 5 minutes. |
| Display dim time‑out (Plugged in) | Logged as an error if the display dim time‑out (Plugged in) is disabled.  Logged as a warning if the display dim time‑out (Plugged in) is set to a value that is greater than 10 minutes. |
| Sleep time‑out (On battery) | Logged as an error if the system sleep time‑out (On battery) is disabled.  Logged as a warning if the system sleep time‑out (On battery) is set to a value that is greater than 30 minutes. |
| Sleep time‑out (Plugged in) | Logged as an error if the system sleep time‑out (Plugged in) is disabled.  Logged as a warning if the system sleep time‑out (Plugged in) is set to a value that is greater than 30 minutes. |
| Disk idle time‑out (On battery) | Logged as an error if the disk time‑out (On battery) is disabled.  Logged as a warning if the disk time‑out (On battery) is set to a value that is greater than 30 minutes. |
| Disk idle time‑out (Plugged in) | Logged as an error if the disk time‑out (Plugged in) is disabled.  Logged as a warning if the disk time‑out (Plugged in) is set to a value that is greater than 30 minutes. |
| Minimum processor performance state (On battery) | Logged as an error if the minimum processor performance state (On battery) is set to 100 percent of the maximum processor performance when the system is on battery power.  Logged as a warning if the minimum processor performance state (On battery) is set to a value that is between 75 and 100 percent of the maximum processor performance when the system is on battery power. |
| Minimum processor performance state (Plugged in) | Logged as an error if the minimum processor performance state (Plugged in) is set to 100 percent of the maximum processor performance.  Logged as a warning if the minimum processor performance state (Plugged in) is set to a value that is between 75 and 100 percent of maximum processor performance when the system is plugged in. |
| Processor idle states enabled (On battery) | Logged as an error if the current power policy has disabled processor idle (C) states when the system is running on battery power. |
| Processor idle states enabled (Plugged in) | Logged as an error if the current power policy has disabled processor idle (C) states when the system is plugged in. |
| Selective suspend policy (On battery) | Logged as an error if the current power policy has disabled USB selective suspend when the system is running on battery power. |
| Selective suspend policy (Plugged in) | Logged as an error if the current power policy has disabled USB selective suspend when the system is plugged in. |
| 802.11 power mode (On battery) | Logged as an error if the 802.11 wireless adapter is set to Maximum Performance when the system is running on battery power. |
| 802.11 power mode (Plugged in) | Logged as a warning if the 802.11 wireless adapter is set to Maximum Performance when the system is plugged in. |
| PCI Express (PCIe) Active State Power Management (ASPM) (On battery) | Logged as an error if PCIe ASPM is disabled in the current power policy when the system is running on battery power. |
| PCIe ASPM (Plugged in) | Logged as an error if PCIe ASPM is disabled in the current power policy when the system is plugged in. |

## Platform Timer Resolution

The platform timer is a periodic timer that drives the Windows kernel scheduler. The system hardware supports a range of timer resolutions. To extend battery life, the system should use as low a timer frequency as possible.

Applications that run on the system can call the **timeBeginPeriod** function to request the system to increase the resolution of the platform timer. For example, some applications request that the resolution of the timer be increased to drive animations or other high-precision multimedia tasks.

PowerCfg inspects the current platform timer period and the maximum timer period that the system supports. The current platform timer period is the time duration between platform timer interrupts. The maximum timer period is the maximum duration between platform timer interrupts (the lowest interrupt frequency) that the system’s hardware can support. The maximum timer period is hardware specific. For most hardware platforms, the maximum timer period is approximately 15.6 milliseconds (ms). The maximum timer period on Itanium-based hardware platforms is 10 ms.

If the current timer period equals the maximum timer period, the system has reached the maximum capability of the hardware to be energy efficient. In this situation, an information item that contains the current timer period is logged in the energy efficiency analysis report.

If the current timer period is less than the maximum timer period, the platform timer interrupt runs at a higher frequency and therefore adversely affects the system's energy efficiency. In this situation, a warning that contains the current and maximum timer periods is logged in the energy efficiency analysis report. Information about any processes that were running on the system that requested an increased timer resolution is also included in the report.

The current timer period should never be greater than the maximum timer period. Information about any processes that were running on the system that requested a timer resolution that is greater than the maximum timer period is also included in the report for reference.

Power users could temporarily resolve the problem by closing any unnecessary applications that request an increased platform timer resolution. Note that, in some cases such as high-precision multimedia tasks, the increased platform timer resolution is requested by design. In this situation, power users must strike a balance between prolonging battery life and achieving the desired performance goals.

We recommend that system manufacturers, IT professionals, and software developers make requests to increase the platform timer resolution only when it is absolutely required. For example, a multimedia application should request an increased platform timer resolution only when the application is actually performing a high-precision task. When the high-precision task is complete, the application should return the platform timer to the maximum platform timer period.

Table 2 provides a summary of the platform timer resolution items that PowerCfg analyzes. For each item that is analyzed, the description indicates how PowerCfg determines whether it is an error, a warning, or information.

Table 2. Platform Timer Resolution Items that PowerCfg Analyzes

|  |  |
| --- | --- |
| Items analyzed | Description |
| Current timer period  Maximum timer period | Logged as a warning if the current timer period is less than the maximum timer period. In this situation, the processes that requested the reduced timer period are also logged in the report.  Logged as information if the current timer period is the same as the maximum timer period. |

## System Availability Requests

Windows enables applications and services to make system availability requests. These requests can affect the power management of the system in the following ways:

* Prevent the display from powering off. For example, an application can make a request for the display to remain on during full-screen DVD playback.
* Prevent the system from automatically entering sleep. For example, an application can make a request for the system to remain on while it downloads files over a network.
* Enable away mode. For example, an application can make a request for the system to enable away mode to record a TV program at a scheduled time. For more information about away mode, see ”Away Mode in Windows Vista” on the WHDC Web site.

Applications and services make system availability requests by calling the **SetThreadExecutionState** or **PowerCreateRequest** function.

Applications and services should make system availability requests only while they are processing a task that requires the availability of the system. However, an incorrectly written application or service might accidentally make a system availability request when it does not actually require the system to be available. This could prevent the display from being turned off or prevent the system from automatically entering sleep. In this situation, the system cannot enter low power states and therefore the energy efficiency of the system is decreased.

PowerCfg inspects the system and logs any applications, services, or device drivers that make system availability requests that prevent the system from automatically turning off the display or entering sleep, or that request the system to enter away mode.

Power users could temporarily resolve the problem by closing any unnecessary applications or services that make these requests. They can also use the PowerCfg ‑**requestoverride** option to override a system availability request that an application or service previously made. Note that, in some of the previous examples, certain user scenarios require these requests. In this situation, power users must strike a balance between prolonging battery life and providing the desired user scenarios.

We recommend that system manufacturers, IT professionals, and software developers make system availability requests only when they absolutely need them.

Table 3 provides a summary of the system availability request items that PowerCfg analyzes. For each item that is analyzed, the description indicates how PowerCfg determines whether it is an error, a warning, or information.

Table 3. System Availability Request Items that PowerCfg Analyzes

|  |  |
| --- | --- |
| Items analyzed | Description |
| System required availability request | Logged as an error if any applications, services, or drivers made a request for the system to not automatically enter sleep. |
| Outstanding display required availability request | Logged as an error if any applications made a request for the system to not automatically turn off the display. |
| Away mode availability request | Logged as an error if any applications or services made a request to enable away mode. |

## USB Selective Suspend

The USB selective suspend feature lets USB device drivers that support selective suspend turn off the USB devices that they control when the devices are idle. When a device is no longer idle, the system turns on the device and resumes normal operation. When the system is idle and all USB devices are suspended, no processor activity is required and therefore the processer can enter a low power state. If any USB device in the system cannot enter the suspended state, the processor cannot enter a low power state even when the system is idle. In this situation, the battery life on such a system could be reduced by as much as 25 percent.

PowerCfg inspects all USB devices in the system and identifies those devices that either do not enter selective suspend or rarely enter the suspended state. An error is logged if a device does not enter selective suspend. A warning is logged if the device rarely enters the suspended state. For every device that is logged as an error or warning, the device name, host controller ID, location, device ID, and port path are included in the report.

Power users could resolve the problem by updating to the latest device driver for any reported devices. If the device is not used, the problem can also be resolved by disabling the corresponding USB host controller through Device Manager or the system BIOS.

We recommend that system manufacturers, IT professionals, and driver developers inspect their USB devices and corresponding device drivers to ensure that they support selective suspend before they provide the devices to end users. Providing updated drivers that support selective suspend through the Internet or other media helps end users to achieve maximum energy efficiency.

Table 4 provides a summary of the USB selective suspend item that PowerCfg analyzes. The description indicates how PowerCfg determines whether it is an error, a warning, or information.

Table 4. USB Selective Suspend Items that PowerCfg Analyzes

|  |  |
| --- | --- |
| Items analyzed | Description |
| USB device drivers | Logged as an error if a device does not support selective suspend or never enters the suspended state during the analysis.  Logged as a warning if a device supports selective suspend, but how long it spent in the suspended state during the analysis period was less than 50 percent. |

## CPU Utilization

To extend battery life, CPU utilization should be less than 2 percent when a system is idle. However, processes or services that run in the background might still utilize the processor when the user is not interacting with the system. This can result in reduced battery life and increased power consumption. For example, if the system provides network services to other systems such as peer-to-peer downloading or the system runs a background calculation such as search indexing, the CPU utilization could increase significantly.

PowerCfg inspects the system’s CPU utilization during the analysis period. An information item is logged if the overall system CPU utilization is less than 2 percent, a warning is logged if the system CPU utilization is between 2 and 4 percent, and an error is logged if the system CPU utilization is greater than 4 percent. PowerCfg also logs individual processes as warnings in the report if their process CPU utilization is greater than 0.2 percent and the system CPU utilization is greater than 2 percent.

To prolong the battery life, we recommend that system manufacturers, IT professionals, and software developers schedule background tasks based on the type of power source that the system currently uses. All these tasks should be run only when the system is plugged in, unless the user specifically requests for a task to be run. The current power source can be determined by using either the **GetSystemPowerStatus** function or the **RegisterPowerSettingNotification** function. For more information about how to develop efficient background processes, see ”Developing Efficient Background Processes for Windows” on the WHDC Web site.

System manufactures, IT professionals, and software developers can use utilities in the Windows Performance Toolkit (WPT) to perform a more thorough analysis of a system's CPU utilization. More information about the WPT is available on the MSDN® Web site.

Power users can temporarily resolve the problem by suspending or stopping the background processes or services that have high CPU utilization. Note that PowerCfg requires the system to be idle for at least 60 seconds during analysis. If the system is not idle during analysis, some active applications are logged as warnings or errors because of their high CPU utilization.

Table 5 provides a summary of the CPU utilization item that PowerCfg analyzes. The description indicates how PowerCfg determines whether it is an error, a warning, or information.

Table 5. CPU Utilization Items that PowerCfg Analyzes

|  |  |
| --- | --- |
| Items analyzed | Description |
| CPU utilization | Logged as an error if the system CPU utilization is greater than 4 percent.  Logged as a warning if the system CPU utilization is between 2 and 4 percent.  Logged as information if the CPU utilization is less than 2 percent.  Also logged as a warning if the CPU utilization for a specific process is greater than 0.2 percent. |

## Battery

The capacity of a system's battery is determined by a number of factors, such as the design capacity of the battery, the capacity of the battery's last full charge, the chemistry of the battery, the battery's internal temperature, and the load on the battery. When the capacity of a system's battery is low, it cannot hold as much energy as it was originally designed to hold. In this situation, the user experiences reduced battery life.

The *design capacity* of a battery is how much energy the battery is designed to hold. The *last full charge capacity* is how much energy the battery held the last time that the battery was fully charged. The last full charge capacity is used as an index for the battery’s current capacity. After a battery is manufactured, the battery’s ability to hold energy decreases over time. Therefore, the last full charge capacity also decreases.

PowerCfg inspects the battery information during the analysis. It logs an information item that contains the battery manufacturer, the battery chemistry, the design capacity, and the last full charge capacity. PowerCfg logs an error if it cannot retrieve the battery information from the firmware. PowerCfg logs a warning if the last full charge capacity is less than 50 percent of the battery's design capacity. PowerCfg logs an error if the last full charge capacity is less than 40 percent of the battery's design capacity.

In some systems, power users might be able to resolve a low last full charge capacity problem by performing a full recalibration cycle on the battery. A recalibration of the battery does not change the actual ability of the battery to store energy, but it does improve the accuracy of the last full charge capacity, which is the index for current battery capacity. On a newer model portable computer, a user might not be required to perform such a recalibration because the system firmware on many new systems contains the recalibration functionality and the firmware performs the recalibration automatically without any recognition by the operating system. A user could also resolve the problem by replacing the system's battery.

Power users could resolve a failure to retrieve the battery information error by updating to the latest version of the system's firmware.

Table 6 provides a summary of the battery items that PowerCfg analyzes. For each item that is analyzed, the description indicates how PowerCfg determines whether it is an error, a warning, or information.

Table 6. Battery Items that PowerCfg Analyzes

|  |  |
| --- | --- |
| Items analyzed | Description |
| Battery information | Typically logged as information.  Logged as an error if the operating system could not retrieve the battery Information from the firmware. |
| Design capacity  Last full charge capacity | Logged as an error if the last full charge capacity is less than 40 percent of the battery's design capacity.  Logged as a warning if the last full charge capacity is between 40 and 50 percent of the battery's design capacity. |

## Platform Power Management

Windows provides a set of platform power management features such as sleep, hibernate, adaptive display brightness, and PCIe ASPM. To achieve optimal energy efficiency, the hardware and the system firmware must provide support for these power management features.

PowerCfg inspects the capabilities of the hardware and system firmware to determine whether they support these power management features. PowerCfg logs errors, warnings, or information items based on the results of the inspection.

Power state transitions from the active power state (S0) to a low power state (S1, S2, S3, or S4) let a system save power when it is idle. These power states are defined in the ACPI specification. An explanation of each state follows:

* Today’s systems rarely use the S1 and S2 power states.
* The S3 power state, also known as *sleep*, consumes only enough power to preserve the contents of the system's memory. A system can resume very quickly from the S3 power state.
* The S4 power state, also known as *hibernate*, consumes no power, but requires longer time to resume compared to the S3 power state.

If a system does not support transitioning to the S3 or S4 power state, it wastes power when it is not being used. PowerCfg inspects the support that the hardware and firmware provide for transitioning to these low power states. PowerCfg logs an error if these low power states are not supported. If the root causes of why these lower power states are not supported can be determined, this information is also logged in the report.

The adaptive display brightness feature enables the operating system to automatically adjust the brightness level of an integrated display based on user interaction with the system. The operating system can reduce the display brightness level if the user does not interact with the system for a specified period of time. If a system does not support adaptive display brightness, it has higher power consumption when the system is idle, which results in reduced battery life. PowerCfg inspects the hardware and firmware to determine whether the system supports adaptive display brightness. If the system does not support adaptive display brightness, PowerCfg logs an error.

If the system supports PCIe, support for ASPM is important for system energy efficiency. ASPM lets each serial link in a PCIe fabric incrementally reduce power as the link becomes less active. PowerCfg inspects the system to check whether it supports PCIe and ASPM. If the system supports PCIe but does not support ASPM, PowerCfg logs an error. For more information about ASPM, see ”Active State Power Management in Windows Vista” on the WHDC Web site.

Power users could resolve some or all of the previously mentioned problems by updating the system's firmware and drivers to the latest versions.

We recommend that system manufacturers verify the system's capabilities before they provide the system to end users.

Table 7 provides a summary of the platform power management items that PowerCfg analyzes. For each item that is analyzed, the description indicates how PowerCfg determines whether it is an error, a warning, or information.

Table 7. Platform Power Management Items that PowerCfg Analyzes

|  |  |
| --- | --- |
| Items analyzed | Description |
| S1, S2, S3, and S4 power states | Logged as an error for any of the following situations:   * The S1 through S4 power states are disabled because the generic video graphics array (VGA) driver is currently loaded. For the system to support the S1 through S4 power states, a specific driver for the particular hardware that is installed in the system is required. * The S3 and/or S4 power state is disabled because the hardware does not support the power state(s). * The S3 and/or S4 power state is disabled because the system firmware does not support the power state(s). * The S1 through S4 power states are disabled in the active power policy. * The S4 power state (hibernate) is disabled because the system has too much physical memory. * The S4 power state (hibernate) is disabled because of a problem in the storage subsystem. * The S4 power state (hibernate) is disabled because the system could not generate or access the hibernation file. * The S1 through S4 power states are disabled because a legacy driver that does not support power management is loaded.   Logged as a warning for the following situation:   * The S3 and/or S4 power state is temporarily disabled by a system component.   Logged as information for any of the following situations:   * The S1 through S4 power states are supported by the system. * The S1 and/or S2 power state is disabled because the hardware does not support the power state. * The S1 and/or S2 power state is temporarily disabled by a system component. |
| Adaptive dis-play brightness | Logged as an error if adaptive display brightness is not supported.  Logged as information if adaptive display brightness is supported. |
| PCIe ASPM | Logged as an error if the system supports PCIe but does not support ASPM. |

## Processor Power Management

Today's processors continue to be the source of a significant portion of overall system power consumption. At the same time, these modern processors offer a rich set of power management features that provide significant power-saving opportunities. The operating system uses the system firmware to set the processors into different performance states, throttle states, and sleep states to achieve the desired energy efficiency and performance goals:

* Setting a processor into a lower *sleep state* sets the whole processor (or at least parts of the processor) into a nonworking state. In this state, the processor no longer runs.
* Setting the processor into a lower *performance state* sets the processor to operate at a lower clock frequency and voltage. In this state, the processor still runs.
* Setting the processor into a lower *throttle state* reduces the speed at which the processor executes instructions. In this state, the processor still runs.

The system firmware must implement a set of ACPI processor objects before the operating system can interact with the processors to set these processor power management states. If the system firmware does not support these ACPI processor objects, it prevents the operating system from being able to put the processors into lower power states, which increases each processor’s power consumption.

PowerCfg inspects the firmware to see whether it supports the required ACPI processor objects and checks that the processor objects behave correctly when the operating system changes the power management settings.

Power users could resolve any problems that PowerCfg identifies by updating the system to the latest version of the system firmware.

We recommend that system manufacturers verify the system's processor power management capabilities before providing the system to end users.

For more information about processor power management, see “Processor Power Management in Windows 7 and Windows Server 2008 R2” and “Processor Power Management in Windows Vista and Windows Server 2008” on the WHDC Web site. For more information about ACPI control methods, see the ACPI specification.

Table 8 provides a summary of the processor power management items that PowerCfg analyzes. For each item that is analyzed, the description indicates how PowerCfg determines whether it is an error, a warning, or information.

Table 8. Processor Power Management Items that PowerCfg Analyzes

|  |  |
| --- | --- |
| Items analyzed | Description |
| Processor sleep states, performance states, and throttle states | Logged as an error in any of the following situations:   * A problem is encountered while the definition for the C2 processor sleep state is validated. * A problem is encountered while the definition for the C3 processor sleep state is validated. * A problem is encountered while the processor throttle states is validated.   Logged as information if the counts of the number of processor sleep states, performance states, and throttle states were successfully retrieved. |
| \_CST ACPI processor object | Logged as an error if a problem is encountered while the \_CST ACPI processor object is validated. The operating system uses this object to set any processor sleep states other than the C1, C2, and C3 processor sleep states that are defined in version 1.0 of the ACPI specification. |
| \_CSD ACPI processor object | Logged as an error if a problem is encountered while the \_CSD ACPI processor object is validated. The operating system uses this object to retrieve the C state dependency information for a particular processor. |
| \_PCT ACPI processor object | Logged as an error if a problem is encountered while the \_PCT ACPI processor object is validated. The operating system uses this object to retrieve the address of the register that the operating system uses to set the performance state for a particular processor. |
| \_PSS ACPI processor object | Logged as an error if a problem is encountered while the \_PSS ACPI processor object is validated. The operating system uses the \_PSS and \_PPC objects to retrieve the performance states that a particular processor supports. |
| \_PPC ACPI processor object | Logged as an error if a problem is encountered while the \_PPC ACPI processor object is validated. The operating system uses the \_PSS and \_PPC objects to retrieve the performance states that a particular processor supports. |
| \_PSD ACPI processor object | Logged as an error if a problem is encountered while the \_PSD ACPI processor object is validated. The operating system uses this object to retrieve the P-state dependency information for a particular processor. |
| \_PTC ACPI processor object | Logged as an error if a problem is encountered while the \_PTC ACPI processor object is validated. The operating system uses this object to retrieve the address of the register that the operating system uses to set the throttle state for a particular processor. |
| \_TSS ACPI processor object | Logged as an error if a problem is encountered while the \_TSS ACPI processor object is validated. The operating system uses the \_TSS and \_TPC objects to retrieve the throttle states that a particular processor supports. |
| \_TPC ACPI processor object | Logged as an error if a problem is encountered while the \_TPC ACPI processor object is validated. The operating system uses the \_TSS and \_TPC objects to retrieve the throttle states that a particular processor supports. |
| \_TSD ACPI processor object | Logged as an error if a problem is encountered while the \_TSD ACPI processor object is validated. The operating system uses this object to retrieve the T-state dependency information for a particular processor. |
| Processor idle state domain member count | Logged as an error if a problem exists about the number of processors that are defined as members of a processor idle state domain. A processor idle state domain is used to define an interdependency among multiple processors in the system for transitions between idle states. |
| Processor performance or throttle state domain member count | Logged as an error if a problem exists about the number of processors that are defined as members of a processor performance or throttle state domain. A processor performance or throttle state domain is used to define an interdependency among multiple processors in the system for transitions between performance or throttle states. |
| Processor idle states | Logged as an error if the C2 processor idle state was disabled because the hardware does not support it. To reserve power, the operating system uses processor idle states to put processors into low power sleep states when the system is idle. |
| Processor performance states | Logged as an error if the processor performance states were disabled because the hardware does not support them. The operating system uses processor performance states to put processors into low-frequency and low-voltage states when the full computing capacity of the system is not required. |
| Processor throttle states | Logged as an error if the processor throttle states were disabled because the hardware does not support them. To reduce power consumption and to produce less heat, the operating system uses processor throttle states to reduce the speed at which a processor executes instructions. |

# Advanced PowerCfg Techniques

The PowerCfg **‑ENERGY** command-line option supports additional parameters for specifying advanced energy efficiency analysis options. PowerCfg can also be instructed to generate an .ETL file for an energy efficient analysis that can be analyzed by using other Microsoft performance analysis tools such as XPerf.

## PowerCfg -ENERGY Parameters

PowerCfg supports several additional optional parameters when the **‑ENERGY** option is specified. To see the usage information for the **‑ENERGY** option, open an elevated command window and run PowerCfg with the **/?** option, as shown in the following example:

C:\>powercfg /?”

. . .

-ENERGY

Analyze the system for common energy-efficiency and battery life

problems. The ENERGY command should be used when the computer is

idle and with no open programs or documents. The ENERGY command

will generate an HTML report file in the current path. The ENERGY

command supports the following optional parameters:

Usage: POWERCFG -ENERGY [-OUTPUT <FILENAME>] [-XML]

[-DURATION <SECONDS>]

POWERCFG -ENERGY -TRACE [-D <FILEPATH>]

[-DURATION <SECONDS>]

-OUTPUT <FILENAME> - Specify the path and filename to store the

energy report HTML file.

-XML - Format the report file as XML.

-TRACE - Record system behavior and do not perform

analysis. Trace files will be generated in

the current path unless the -D parameter

is specified.

-D <FILEPATH> - Specify the directory to store trace data.

May only be used with the -TRACE parameter.

-DURATION <SECONDS> - Specify the number of seconds to observe

system behavior. Default is 60 seconds.

The following describes the optional parameters that the PowerCfg **-ENERGY** option supports.

‑OUTPUT <FILENAME>

Specifies the path and file name where the energy efficiency analysis report is saved. If this parameter is not specified, the default file name for the report is *energy‑report.html*, and it is saved in the current directory.

For example:

powercfg ‑energy ‑output c:\energy\energy-report-1.html

In this example, the energy efficiency analysis report is saved as the *energy‑report‑1.html* file in the *c:\energy\* directory.

-DURATION <SECONDS>

Specifies the duration of the energy efficiency analysis. The default duration is 60 seconds. To analyze smaller or larger periods of time, the duration can be changed. Changing the duration of the analysis is most useful when processor utilization, USB device selective suspend, or other time-specific energy efficiency problems are analyzed, as shown in the following example:

powercfg - energy -duration 120

In this example, the energy efficiency analysis runs for 120 seconds.

-TRACE

Specifies that the energy efficiency data should be collected, but no analysis of the data is to be performed and no energy efficiency analysis report file is to be saved. Instead, event tracing for Windows (ETW) data files that are named *energy‑trace.etl* and *energy‑ntkl.etl* are saved in the current directory. The *energy‑trace.etl* file contains the ETW events, and the *energy‑ntkl.etl* file contains the NT kernel logger events, as shown in the following example:

powercfg -energy –trace

In this example, the energy efficiency data is collected and saved in the *energy‑trace.etl* and *energy‑ntkl.etl* files in the current directory. No analysis of the data is performed, and no energy efficiency analysis report is saved.

-D <FILEPATH>

Specifies the path where the ETW data files are saved when the -TRACE parameter is specified, as shown in the following example:

powercfg ‑energy ‑trace ‑d c:\energy

In this example, the *energy‑trace.etl* and *energy‑ntkl.etl* ETW data files are saved in the *c:/energy* directory.

-XML

Specifies that the energy efficiency report file is saved in XML format. If this parameter is not specified, the default file format is HTML. The HTML file format is designed for most PowerCfg users because it is easy to read. The XML file format is designed for advanced users of PowerCfg because it is easy to parse and to be represented in other formats. Specifying the XML file format is shown in the following example:

powercfg -energy –xml

In this example, the energy efficiency analysis report is saved in XML format as the *energy‑report.xml* file in the current directory.

Many of these parameters can be used in combination with one another, as shown in the following example:

powercfg ‑energy ‑output c:\energy\example-report.html -duration 30

In this example, the energy efficiency analysis is run for 30 seconds and the report is saved as the *example-report.html* file in the *c:\energy* directory.

## Reviewing Trace Data with the Windows Performance Toolkit

When the **‑TRACE** parameter is specified, PowerCfg generates ETW data files. These ETW files can be opened and analyzed by using the WPT. More information about the WPT is available on the MSDN Web site.

# Troubleshooting the PowerCfg -ENERGY Command

Several common errors can occur when you use PowerCfg with the **‑ENERGY** option. The following sections provide information about each of these common errors and how to resolve the problem.

## Multiple NT Kernel Logger Consumers

The functionality that the PowerCfg **-ENERGY** option provides is built upon ETW. Many Windows performance analysis utilities consume ETW instrumentation, including Performance and Reliability Monitor (PerfMon.msc) and XPerf.

Certain ETW instrumentation from the Windows kernel is available to only one utility at any time. This instrumentation comes from a unique ETW logger that is called the *NT Kernel Logger* and includes processor utilization and device identification Information.

If another performance analysis utility is using the instrumentation from the NT Kernel Logger when an energy efficiency analysis is run, PowerCfg cannot initiate data tracing or analysis. In this situation, the following error message appears:

C:\energy>powercfg -energy

Enabling tracing for 60 seconds...

Observing system behavior...

Could not open the NT Kernel Logger. The NT Kernel Logger is already in use. Ensure that all other performance monitoring utilities, including Reliability and Performance Monitor are not currently in use.

The most common cause of this problem is that PerfMon is open and running on the system when the energy efficiency analysis is run. To fix this problem, close all other performance analysis utilities before you run the energy efficiency analysis.

## Unexpected Termination of PowerCfg

If PowerCfg is unexpectedly stopped while it is running an energy efficiency analysis, subsequent attempts to run an energy efficiency analysis fail. In this situation, the following error message appears:

C:\energy>powercfg -energy

Enabling tracing for 60 seconds...

Observing system behavior...

Energy Efficiency Wizard Logger already in use.

Could not open the Energy Efficiency Wizard ETW session. The ETW session is already in use. Ensure that no other instances of the Energy Efficiency Wizard are currently running.

The most common cause of this problem is that the user stopped the energy efficiency analysis by typing CTRL‑C before the analysis completed. The solution to this problem is to restart the system.

# Conclusion

Ensuring maximum system energy efficiency requires cooperation from all platform components, including hardware, firmware, applications, services, devices, and drivers. PowerCfg, which is included with Windows, is enhanced for Windows 7 to help discover energy efficiency problems and to validate that a particular component is not adversely affecting the overall energy efficiency of the system.

We recommend that system manufacturers run an energy efficiency analysis on all new systems. They should verify that no errors are logged in the energy efficiency report before they ship their systems to customers.

IT professionals can also run an energy efficiency analysis to diagnose and find the cause of an end-user problem with portable computer battery life or desktop computer power consumption.

# Resources

ACPI specification

<http://www.acpi.info/>

Active State Power Management in Windows Vista

<http://www.microsoft.com/whdc/connect/pci/aspm.mspx>

Away Mode in Windows Vista

<http://www.microsoft.com/whdc/system/pnppwr/powermgmt/awaymode.mspx>

Developing Efficient Background Processes for Windows

<http://www.microsoft.com/whdc/system/pnppwr/powermgmt/BackgroundProcs.mspx>

Mobile Battery Solutions Guide for Windows Vista

<http://www.microsoft.com/whdc/system/pnppwr/mobile_bat.mspx>

Optimizing Windows Vista Platforms for Energy Efficiency

<http://www.microsoft.com/whdc/system/pnppwr/powermgmt/Optimize_Power.mspx>

Power Policy Configuration and Deployment in Windows

<http://www.microsoft.com/whdc/system/pnppwr/powermgmt/PMpolicy_Windows.mspx>

Processor Power Management in Windows 7 and Windows Server 2008 R2

<http://www.microsoft.com/whdc/system/pnppwr/powermgmt/ProcPowerMgmtWin7.mspx>

Processor Power Management in Windows Vista and Windows Server 2008

<http://www.microsoft.com/whdc/system/pnppwr/powermgmt/ProcPowerMgmt.mspx>

Windows Performance Toolkit

<http://www.microsoft.com/downloads/details.aspx?FamilyID=c17ba869-9671-4330-a63e-1fd44e0e2505&displaylang=en>