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# Cost Optimization Pillar

## **AWS Well-Architected Framework**

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## **Cost Optimization Pillar: AWS Well-Architected Framework**

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# Cost Optimization Pillar - AWS Well-Architected Framework

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## Abstract

This whitepaper focuses on the cost optimization pillar of the Amazon Web Services (AWS) Well-Architected Framework. It provides guidance to help customers apply best practices in the design, delivery, and maintenance of AWS environments.

A cost-optimized workload fully utilizes all resources, achieves an outcome at the lowest possible price point, and meets your functional requirements. This whitepaper provides in-depth guidance for building capability within your organization, designing your workload, selecting your services, configuring and operating the services, and applying cost optimization techniques.

## Introduction

The [AWS Well-Architected Framework](#) helps you understand the decisions you make while building workloads on AWS. The Framework provides architectural best practices for designing and operating reliable, secure, efficient, cost-effective, and sustainable workloads in the cloud. It demonstrates a way to consistently measure your architectures against best practices and identify areas for improvement. We believe that having well-architected workloads greatly increases the likelihood of business success.

The framework is based on six pillars:

- Operational Excellence
- Security
- Reliability
- Performance Efficiency
- Cost Optimization
- Sustainability

This paper focuses on the cost optimization pillar, and how to architect workloads with the most effective use of services and resources, to achieve business outcomes at the lowest price point.

You'll learn how to apply the best practices of the cost optimization pillar within your organization. Cost optimization can be challenging in traditional on-premises solutions because you must predict future capacity and business needs while navigating complex procurement processes. Adopting the practices in this paper will help your organization achieve the following goals:

- Practice Cloud Financial Management
- Expenditure and usage awareness
- Cost effective resources
- Manage demand and supply resources

- Optimize over time

This paper is intended for those in technology and finance roles, such as chief technology officers (CTOs), chief financial officers (CFOs), architects, developers, financial controllers, financial planners, business analysts, and operations team members. This paper does not provide implementation details or architectural patterns, however, it does include references to appropriate resources.

# Cost optimization

Cost optimization is a continual process of refinement and improvement over the span of a workload's lifecycle. The practices in this paper help you build and operate cost-aware workloads that achieve business outcomes while minimizing costs and allowing your organization to maximize its return on investment.

## Topics

- [Design principles \(p. 3\)](#)
- [Definition \(p. 3\)](#)

## Design principles

Consider the following design principles for cost optimization:

**Implement cloud financial management:** To achieve financial success and accelerate business value realization in the cloud, you must invest in Cloud Financial Management. Your organization must dedicate the necessary time and resources for building capability in this new domain of technology and usage management. Similar to your Security or Operations capability, you need to build capability through knowledge building, programs, resources, and processes to help you become a cost efficient organization.

**Adopt a consumption model:** Pay only for the computing resources you consume, and increase or decrease usage depending on business requirements. For example, development and test environments are typically only used for eight hours a day during the work week. You can stop these resources when they're not in use for a potential cost savings of 75% (40 hours versus 168 hours).

**Measure overall efficiency:** Measure the business output of the workload and the costs associated with delivery. Use this data to understand the gains you make from increasing output, increasing functionality, and reducing cost.

**Stop spending money on undifferentiated heavy lifting:** AWS does the heavy lifting of data center operations like racking, stacking, and powering servers. It also removes the operational burden of managing operating systems and applications with managed services. This allows you to focus on your customers and business projects rather than on IT infrastructure.

**Analyze and attribute expenditure:** The cloud makes it easier to accurately identify the cost and usage of workloads, which then allows transparent attribution of IT costs to revenue streams and individual workload owners. This helps measure return on investment (ROI) and gives workload owners an opportunity to optimize their resources and reduce costs.

## Definition

There are five focus areas for cost optimization in the cloud:

- Practice Cloud Financial Management
- Expenditure and usage awareness
- Cost-effective resources
- Manage demand and supplying resources

- Optimize over time

Similar to the other pillars within the Well-Architected Framework, there are trade-offs to consider for cost optimization. For example, whether to optimize for speed-to-market, or for cost. In some cases, it's best to optimize for speed—going to market quickly, shipping new features, or meeting a deadline—rather than investing in upfront cost optimization.

Design decisions are sometimes directed by haste rather than data, and the temptation always exists to overcompensate, rather than spend time benchmarking for the most cost-optimal deployment. Overcompensation can lead to over-provisioned and under-optimized deployments. However, it may be a reasonable choice if you must “lift and shift” resources from your on-premises environment to the cloud and then optimize afterwards.

Investing the right amount of effort in a cost optimization strategy up front allows you to realize the economic benefits of the cloud more readily by ensuring a consistent adherence to best practices and avoiding unnecessary over provisioning. The following sections provide techniques and best practices for the initial and ongoing implementation of Cloud Financial Management and cost optimization for your workloads.



# Practice Cloud Financial Management

Managing cloud finance requires evolving your existing finance processes to establish and operate with cost transparency, control, planning, and optimization for your AWS environments.

Applying traditional, static waterfall planning, IT budgeting, and cost assessment models to dynamic cloud usage can create risks, lead to inaccurate planning, and result in less visibility. Ultimately, this results in a lost opportunity to effectively optimize and control costs and realize long-term business value. To avoid these pitfalls, actively manage costs throughout the cloud journey, whether you are building applications natively in the cloud, migrating your workloads to the cloud, or expanding your adoption of cloud services.

*Cloud Financial Management* (CFM) allows finance, product, technology, and business organizations to manage, optimize, and plan costs as they grow their usage and scale on AWS. The primary goal of CFM is to allow customers to achieve their business outcomes in the most cost-efficient manner and accelerate economic and business value creation while finding the right balance between agility and control.

CFM solutions help transform your business through cost transparency, control, forecasting, and optimization. These solutions can also create a cost-conscious culture that drives accountability across all teams and functions. Finance teams can see where costs are coming from, run operations with minimal unexpected expenses, plan for dynamic cloud usage, and save on cloud expenses while teams scale their adoptions in the cloud. Sharing this with engineering teams can provide necessary financial context for their resource selection, use, and optimization.

AWS CFM offers a set of capabilities to manage, optimize, and plan for cloud costs while maintaining business agility. CFM is paramount not only to effectively manage costs, but also to verify that investments are driving expected business outcomes. These are the four pillars of the Cloud Financial Management Framework in the AWS Cloud: *see, save, plan, and run*. Each of these pillars has a set of activities and capabilities.



*The four pillars of Cloud Financial Management.*

- **See:** How are you currently measuring, monitoring and creating accountability for your cloud spend? If you are new to AWS or planning on using AWS, do you have a plan to establish cost and usage visibility?

To understand your AWS costs and optimize spending, you need to know where those costs are coming from. This requires a deliberate structure for your accounts and resources, helping your finance organization track spending flows and hold teams accountable for their portion of the bottom line.

**AWS Services:** AWS Control Tower, AWS Organizations, Cost allocations tags, Tag policies, AWS Resource Groups, AWS Cost Categories, AWS Cost Explorer, AWS Cost and Usage Report, RIs and SPs

**Resources:** AWS Tagging Best Practices, AWS Cost Categories

- **Save:** What cost optimization levers are you currently using to optimize your spend? If you are not using AWS, are you familiar with common usage-based and pricing model-based optimizations?

In the save tenet, we optimize costs with pricing and resource recommendations. Optimizing costs begins with having a well-defined strategy for your new cloud operating model. Ideally, this should start as early as possible in your cloud journey, setting the stage for a cost-conscious culture reinforced by the right processes and behaviors.

There are many different ways you can optimize cloud costs. One of them is selecting the right purchase model (RIs and SPs) or whether your workload is immutable and containerized so that you can adopt Amazon EC2 Spot Instances. In addition, scale your workload using Amazon EC2 Auto Scaling Groups.

**AWS Services:** RIs and SPs, Amazon EC2 Auto Scaling Groups, Spot Instances

**Resources:** Reserved Instances, Savings Plans, Best practices for handling Amazon EC2

- **Plan:** How do you currently plan for future cloud usage and spend? Do you have a methodology to quantify value generation for a new migration? Have you evolved your current budgeting and forecasting processes to adopt variable usage of the cloud?

The plan tenet means improving your planning with flexible budgeting and forecasting. Once you've established visibility and cost controls, you will likely want to plan and set expectations for spending on cloud projects. AWS gives you the flexibility to build dynamic forecasting and budgeting processes so you can stay informed on whether costs adhere to, or exceed, budgetary limits.

**AWS Services:** AWS Cost Explorer, AWS Cost and Usage Report, AWS Budgets

**Resources:** Usage-Based Forecasting, AWS Budget Reports and Alerts

- **Run:** What are some of the operational processes and tools you are currently using to manage your cloud expenditures, and who is leading those efforts? Have you put any thought into how things will work from a daily operations perspective once you start using AWS?

The run tenet is actually managing billing and cost control. You can establish guardrails and set governance to ensure expenses stay in line with budgets. AWS provides several tools to help you get started.

**AWS Services:** AWS Billing and Cost Management Console, AWS Identity and Access Management, Service Control Policies (SCP), AWS Service Catalog, AWS Cost Anomaly Detection, AWS Budgets

**Resources:** Getting Started with AWS Billing Console

The following are Cloud Financial Management best practices:

#### Best practices

- [COST01-BP01 Establish a cost optimization function \(p. 7\)](#)
- [COST01-BP02 Establish a partnership between finance and technology \(p. 9\)](#)
- [COST01-BP03 Establish cloud budgets and forecasts \(p. 13\)](#)
- [COST01-BP04 Implement cost awareness in your organizational processes \(p. 14\)](#)

- [COST01-BP05 Report and notify on cost optimization \(p. 16\)](#)
- [COST01-BP06 Monitor cost proactively \(p. 17\)](#)
- [COST01-BP07 Keep up-to-date with new service releases \(p. 18\)](#)
- [COST01-BP08 Create a cost-aware culture \(p. 19\)](#)
- [COST01-BP09 Quantify business value from cost optimization \(p. 21\)](#)

## COST01-BP01 Establish a cost optimization function

Create a team (Cloud Business Office or Cloud Center of Excellence) that is responsible for establishing and maintaining cost awareness across your organization. The team requires people from finance, technology, and business roles across the organization.

**Level of risk exposed if this best practice is not established:** High

### Implementation guidance

Establish a Cloud Business Office (CBO) or Cloud Center of Excellence (CCOE) team that is responsible for establishing and maintaining a culture of cost awareness in cloud computing. It can be an existing individual, a team within your organization, or a new team of key finance, technology and organization stakeholders from across the organization.

The function (individual or team) prioritizes and spends the required percentage of their time on cost management and cost optimization activities. For a small organization, the function might spend a smaller percentage of time compared to a full-time function for a larger enterprise.

The function requires a multi-disciplined approach, with capabilities in project management, data science, financial analysis, and software or infrastructure development. The function can improve efficiencies of workloads by running cost optimizations within three different ownerships:

- **Centralized:** Through designated teams such as finance operations, cost optimization, CBO, or CCOE, customers can design and implement governance mechanisms and drive best practices company-wide.
- **Decentralized:** Influencing technology teams to run optimizations.
- **Hybrid:** A combination of both centralized and decentralized teams can work together to run cost optimizations.

The function may be measured against their ability to run and deliver against cost optimization goals (for example, workload efficiency metrics).

You must secure executive sponsorship for this function to make changes, which is a key success factor. The sponsor is regarded as champion for cost efficient cloud consumption, and provides escalation support for the function to ensure that cost optimization activities are treated with the level of priority defined by the organization. Otherwise, guidance will be ignored and cost-saving opportunities will not be prioritized. Together, the sponsor and function ensure that your organization consumes the cloud efficiently and continues to deliver business value.

If you have a Business, Enterprise-On-Ramp, or Enterprise Support plan, and need help to build this team or function, reach out to Cloud Finance Management (CFM) experts through your Account team.

### Implementation steps

- **Define key members:** You need to ensure that all relevant parts of your organization contribute and have a stake in cost management. Common teams within organizations typically include: finance, application or product owners, management, and technical teams (DevOps). Some are engaged full time (finance, technical), others periodically as required. Individuals or teams performing CFM generally need the following set of skills:
  - Software development skills - in the case where scripts and automation are being built out.
  - Infrastructure engineering skills - to deploy scripts or automation, and understand how services or resources are provisioned.
  - Operations acumen - CFM is about operating on the cloud efficiently by measuring, monitoring, modifying, planning and scaling efficient use of the cloud.
- **Define goals and metrics:** The function needs to deliver value to the organization in different ways. These goals are defined and continually evolve as the organization evolves. Common activities include: creating and running education programs on cost optimization across the organization, developing organization-wide standards, such as monitoring and reporting for cost optimization, and setting workload goals on optimization. This function also needs to regularly report to the organization on the organization's cost optimization capability.

You can define value-based key performance indicators (KPIs). KPIs can be cost-based or value-based. When you define the KPIs, you can calculate expected cost in terms of efficiency and expected business outcome. Value-based KPIs tie cost and usage metrics to business value drivers and help us rationalize changes in our AWS spend. The first step to deriving value-based KPIs is working together, cross-organizationally, to select and agree upon a standard set of KPIs.

- **Establish regular cadence:** The group (finance, technology, and business teams) should come together regularly to review their goals and metrics. A typical cadence involves reviewing the state of the organization, reviewing any programs currently running, and reviewing overall financial and optimization metrics. Then key workloads are reported on in greater detail.

During these regular meetings, you can review workload efficiency (cost) and business outcome. For example, a 20% cost increase for a workload may align with increased customer usage. In this case, this 20% cost increase can be interpreted as an investment. These regular cadence calls can help teams to identify value-based KPIs that provide meaning to the entire organization.

## Resources

### Related documents:

- [AWS CCOE Blog](#)
- [Creating Cloud Business Office](#)
- [CCOE - Cloud Center of Excellence](#)

### Related videos:

- [Vanguard CCOE Success Story](#)

### Related examples:

- [Using a Cloud Center of Excellence \(CCOE\) to Transform the Entire Enterprise](#)
- [Building a CCOE to transform the entire enterprise](#)
- [7 Pitfalls to Avoid When Building CCOE](#)

## COST01-BP02 Establish a partnership between finance and technology

Involve finance and technology teams in cost and usage discussions at all stages of your cloud journey. Teams regularly meet and discuss topics such as organizational goals and targets, current state of cost and usage, and financial and accounting practices.

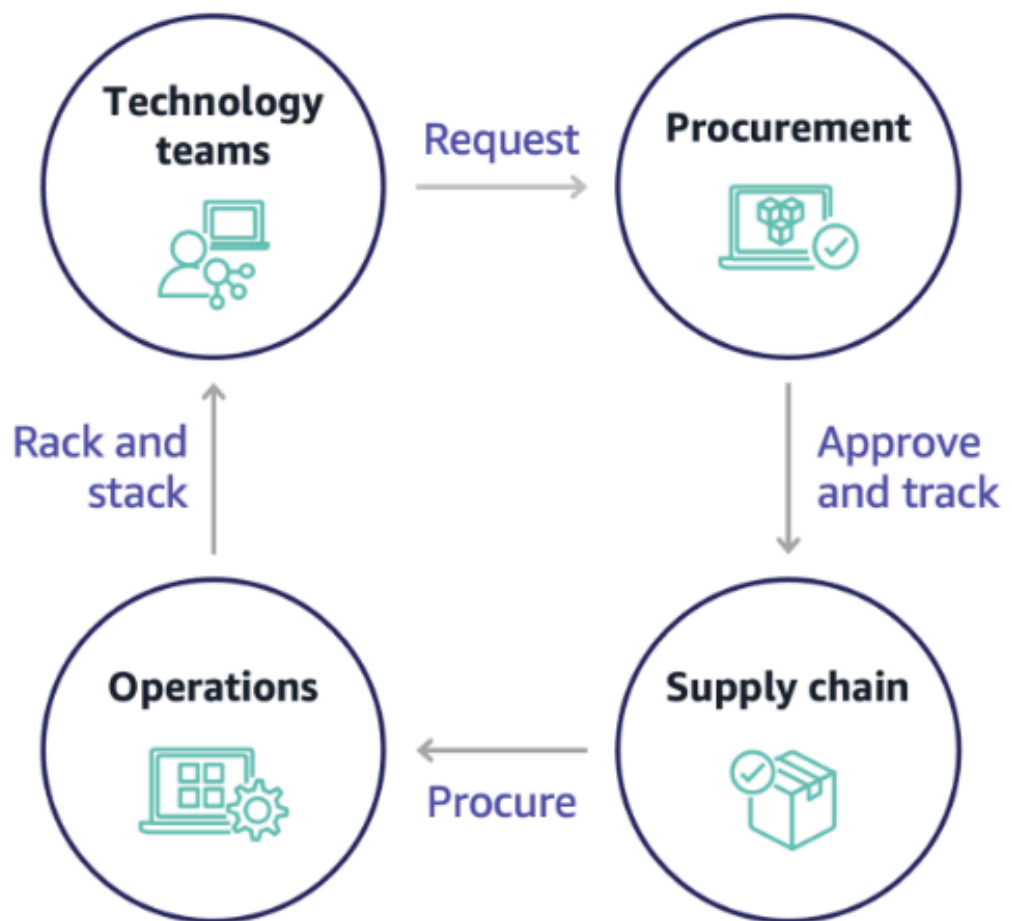
**Level of risk exposed if this best practice is not established:** High

### Implementation guidance

Technology teams innovate faster in the cloud due to shortened approval, procurement, and infrastructure deployment cycles. This can be an adjustment for finance organizations previously used to running time-consuming and resource-intensive processes for procuring and deploying capital in data center and on-premises environments, and cost allocation only at project approval.

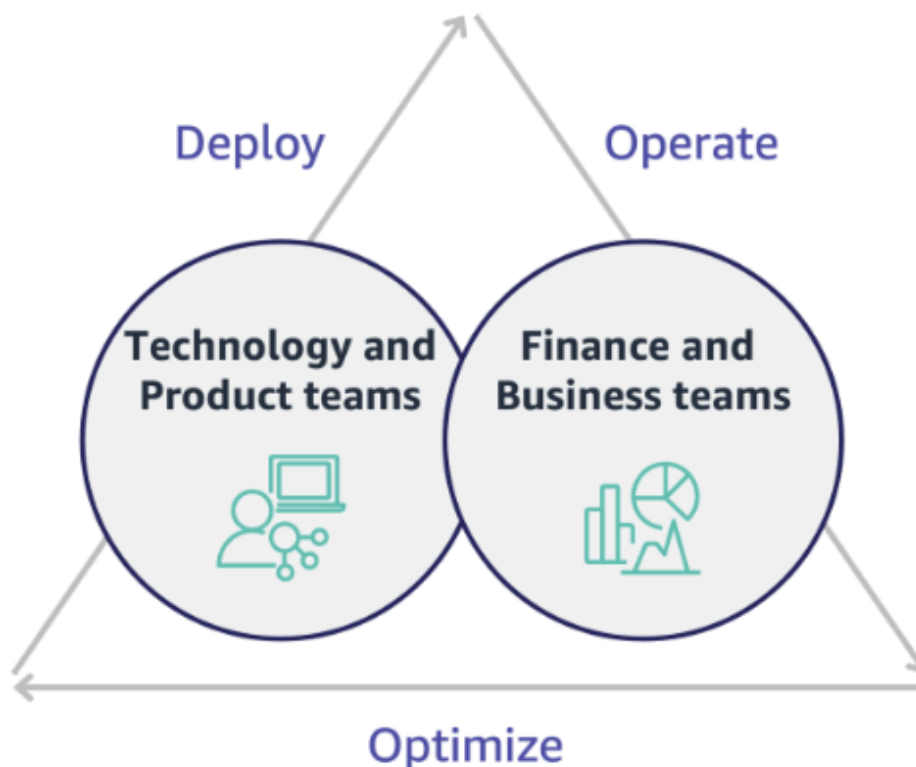
From a finance and procurement organization perspective, the process for capital budgeting, capital requests, approvals, procurement, and installing physical infrastructure is one that has been learned and standardized over decades:

- Engineering or IT teams are typically the requesters
- Various finance teams act as approvers and procurers
- Operations teams rack, stack, and hand off ready-to-use infrastructure



With the adoption of cloud, infrastructure procurement and consumption are no longer beholden to a chain of dependencies. In the cloud model, technology and product teams are no longer just builders, but operators and owners of their products, responsible for most of the activities historically associated with finance and operations teams, including procurement and deployment.

All it really takes to provision cloud resources is an account, and the right set of permissions. This is also what reduces IT and finance risk; which means teams are always a just few clicks or API calls away from terminating idle or unnecessary cloud resources. This is also what allows technology teams to innovate faster – the agility and ability to spin up and then tear down experiments. While the variable nature of cloud consumption may impact predictability from a capital budgeting and forecasting perspective, cloud provides organizations with the ability to reduce the cost of over-provisioning, as well as reduce the opportunity cost associated with conservative under-provisioning.



Establish a partnership between key finance and technology stakeholders to create a shared understanding of organizational goals and develop mechanisms to succeed financially in the variable spend model of cloud computing. Relevant teams within your organization must be involved in cost and usage discussions at all stages of your cloud journey, including:

- **Financial leads:** CFOs, financial controllers, financial planners, business analysts, procurement, sourcing, and accounts payable must understand the cloud model of consumption, purchasing options, and the monthly invoicing process. Finance needs to partner with technology teams to create and socialize an IT value story, helping business teams understand how technology spend is linked to business outcomes. This way, technology expenditures are viewed not as costs, but rather as investments. Due to the fundamental differences between the cloud (such as the rate of change in usage, pay as you go pricing, tiered pricing, pricing models, and detailed billing and usage information) compared to on-premises operation, it is essential that the finance organization understands how cloud usage can impact business aspects including procurement processes, incentive tracking, cost allocation and financial statements.
- **Technology leads:** Technology leads (including product and application owners) must be aware of the financial requirements (for example, budget constraints) as well as business requirements (for example, service level agreements). This allows the workload to be implemented to achieve the desired goals of the organization.

The partnership of finance and technology provides the following benefits:

- Finance and technology teams have near real-time visibility into cost and usage.
- Finance and technology teams establish a standard operating procedure to handle cloud spend variance.

- Finance stakeholders act as strategic advisors with respect to how capital is used to purchase commitment discounts (for example, Reserved Instances or AWS Savings Plans), and how the cloud is used to grow the organization.
- Existing accounts payable and procurement processes are used with the cloud.
- Finance and technology teams collaborate on forecasting future AWS cost and usage to align and build organizational budgets.
- Better cross-organizational communication through a shared language, and common understanding of financial concepts.

Additional stakeholders within your organization that should be involved in cost and usage discussions include:

- **Business unit owners:** Business unit owners must understand the cloud business model so that they can provide direction to both the business units and the entire company. This cloud knowledge is critical when there is a need to forecast growth and workload usage, and when assessing longer-term purchasing options, such as Reserved Instances or Savings Plans.
- **Engineering team:** Establishing a partnership between finance and technology teams is essential for building a cost-aware culture that encourages engineers to take action on Cloud Financial Management (CFM). One of the common problems of CFM or finance operations practitioners and finance teams is getting engineers to understand the whole business on cloud, follow best practices, and take recommended actions.
- **Third parties:** If your organization uses third parties (for example, consultants or tools), ensure that they are aligned to your financial goals and can demonstrate both alignment through their engagement models and a return on investment (ROI). Typically, third parties will contribute to reporting and analysis of any workloads that they manage, and they will provide cost analysis of any workloads that they design.

Implementing CFM and achieving success requires collaboration across finance, technology, and business teams, and a shift in how cloud spend is communicated and evaluated across the organization. Include engineering teams so that they can be part of these cost and usage discussions at all stages, and encourage them to follow best practices and take agreed-upon actions accordingly.

### Implementation steps

- **Define key members:** Verify that all relevant members of your finance and technology teams participate in the partnership. Relevant finance members will be those having interaction with the cloud bill. This will typically be CFOs, financial controllers, financial planners, business analysts, procurement, and sourcing. Technology members will typically be product and application owners, technical managers and representatives from all teams that build on the cloud. Other members may include business unit owners, such as marketing, that will influence usage of products, and third parties such as consultants, to achieve alignment to your goals and mechanisms, and to assist with reporting.
- **Define topics for discussion:** Define the topics that are common across the teams, or will need a shared understanding. Follow cost from that time it is created, until the bill is paid. Note any members involved, and organizational processes that are required to be applied. Understand each step or process it goes through and the associated information, such as pricing models available, tiered pricing, discount models, budgeting, and financial requirements.
- **Establish regular cadence:** To create a finance and technology partnership, establish a regular communication cadence to create and maintain alignment. The group needs to come together regularly against their goals and metrics. A typical cadence involves reviewing the state of the organization, reviewing any programs currently running, and reviewing overall financial and optimization metrics. Then key workloads are reported on in greater detail.



## Resources

### Related documents:

- [AWS News Blog](#)

## COST01-BP03 Establish cloud budgets and forecasts

Adjust existing organizational budgeting and forecasting processes to be compatible with the highly variable nature of cloud costs and usage. Processes must be dynamic using trend-based or business driver-based algorithms, or a combination of both.

**Level of risk exposed if this best practice is not established:** High

## Implementation guidance

Customers use the cloud for efficiency, speed and agility, which creates a highly variable amount of cost and usage. Costs can decrease with increases in workload efficiency, or as new workloads and features are deployed. It is possible to see the cost increase when the workload efficiency increases, or as new workloads and features are deployed. Or, workloads will scale to serve more of your customers, which increases cloud usage and costs. Resources are now more readily accessible than ever before. With the elasticity of the cloud also brings an elasticity of costs and forecasts. Existing organizational budgeting processes must be modified to incorporate this variability.

Adjust existing budgeting and forecasting processes to become more dynamic using either a trend-based algorithm (using historical costs as inputs), or using business-driver-based algorithms (for example, new product launches or regional expansion), or a combination of both trend and business drivers.

Use [AWS Budgets](#) to set custom budgets at a granular level by specifying the time period, recurrence, or amount (fixed or variable), and adding filters such as service, AWS Region, and tags. To stay informed on the performance of your existing budgets you can create and schedule [AWS Budgets Reports](#) to be emailed to you and your stakeholders on a regular cadence. You can also create [AWS Budgets Alerts](#) based on actual costs, which is reactive in nature, or on forecasted costs, which provides time to implement mitigations against potential cost overruns. You will be alerted when your cost or usage exceeds, or if they are forecasted to exceed, your budgeted amount.

AWS gives you the flexibility to build dynamic forecasting and budgeting processes so you can stay informed on whether costs adhere to, or exceed, budgetary limits.

Use [AWS Cost Explorer](#) to forecast costs in a defined future time range based on your past spend. AWS Cost Explorer's forecasting engine segments your historical data based on charge types (for example, Reserved Instances) and uses a combination of machine learning and rule-based models to predict spend across all charge types individually. Use [AWS Cost Explorer](#) to forecast daily (up to three months) or monthly (up to 12 months) cloud costs based on machine learning algorithms applied to your historical costs (trend-based).

Once you've determined your trend-based forecast using Cost Explorer, use the [AWS Pricing Calculator](#) to estimate your AWS use case and future costs based on the expected usage (traffic, requests-per-second, required Amazon Elastic Compute Cloud (Amazon EC2) instance, and so forth). You can also use it to help you plan how you spend, find cost saving opportunities, and make informed decisions when using AWS.

Use [AWS Cost Anomaly Detection](#) to prevent or reduce cost surprises and enhance control without slowing innovation. AWS Cost Anomaly Detection leverages advanced machine learning technologies to

identify anomalous spend and root causes, so you can quickly take action. [With three simple steps](#), you can create your own contextualized monitor and receive alerts when any anomalous spend is detected. Let builders build, and let AWS Cost Anomaly Detection monitor your spend and reduce the risk of billing surprises.

As mentioned in the [Well-Architected Cost Optimization Pillar's Finance and Technology Partnership](#) section, it is important to have partnership and cadences between IT, Finance and other stakeholders to ensure that they are all using the same tooling or processes for consistency. In cases where budgets may need to change, increasing cadence touch points can help react to those changes more quickly.

#### Implementation steps

- **Update existing budget and forecasting processes:** Implement trend-based, business driver-based, or a combination of both in your budgeting and forecasting processes.
- **Configure alerts and notifications:** Use AWS Budgets Alerts and Cost Anomaly Detection.
- **Perform regular reviews with key stakeholders:** For example, stakeholders in IT, Finance, Platform, and other areas of the business, to align with changes in business direction and usage.

## Resources

#### Related documents:

- [AWS Cost Explorer](#)
- [AWS Budgets](#)
- [AWS Pricing Calculator](#)
- [AWS Cost Anomaly Detection](#)
- [AWS License Manager](#)

#### Related examples:

- [Launch: Usage-Based Forecasting now Available in AWS Cost Explorer](#)
- [AWS Well-Architected Labs - Cost and Usage Governance](#)

# COST01-BP04 Implement cost awareness in your organizational processes

Implement cost awareness, create transparency, and accountability of costs into new or existing processes that impact usage, and leverage existing processes for cost awareness. Implement cost awareness into employee training.

**Level of risk exposed if this best practice is not established:** High

## Implementation guidance

Cost awareness must be implemented in new and existing organizational processes. It is one of the foundational, prerequisite capabilities for other best practices. It is recommended to reuse and modify existing processes where possible — this minimizes the impact to agility and velocity. Report cloud costs to the technology teams and the decision makers in the business and finance teams to raise

cost awareness, and establish efficiency key performance indicators (KPIs) for finance and business stakeholders. The following recommendations will help implement cost awareness in your workload:

- Verify that change management includes a cost measurement to quantify the financial impact of your changes. This helps proactively address cost-related concerns and highlight cost savings.
- Verify that cost optimization is a core component of your operating capabilities. For example, you can leverage existing incident management processes to investigate and identify root causes for cost and usage anomalies or cost overruns.
- Accelerate cost savings and business value realization through automation or tooling. When thinking about the cost of implementing, frame the conversation to include an return on investment (ROI) component to justify the investment of time or money.
- Allocate cloud costs by implementing showbacks or chargebacks for cloud spend, including spend on commitment-based purchase options, shared services and marketplace purchases to drive most cost-aware cloud consumption.
- Extend existing training and development programs to include cost-awareness training throughout your organization. It is recommended that this includes continuous training and certification. This will build an organization that is capable of self-managing cost and usage.
- Take advantage of free AWS native tools such as [AWS Cost Anomaly Detection](#), [AWS Budgets](#), and [AWS Budgets Reports](#).

When organizations consistently adopt [Cloud Financial Management](#) (CFM) practices, those behaviours become ingrained in the way of working and decision-making. The result is a culture that is more cost-aware, from developers architecting a new born-in-the-cloud application, to finance managers analyzing the ROI on these new cloud investments.

#### Implementation steps

- **Identify relevant organizational processes:** Each organizational unit reviews their processes and identifies processes that impact cost and usage. Any processes that result in the creation or termination of a resource need to be included for review. Look for processes that can support cost awareness in your business, such as incident management and training.
- **Establish self-sustaining cost-aware culture:** Make sure all the relevant stakeholders align with cause-of-change and impact as a cost so that they understand cloud cost. This will allow your organization to establish a self-sustaining cost-aware culture of innovation.
- **Update processes with cost awareness:** Each process is modified to be made cost aware. The process may require additional pre-checks, such as assessing the impact of cost, or post-checks validating that the expected changes in cost and usage occurred. Supporting processes such as training and incident management can be extended to include items for cost and usage.

To get help, reach out to CFM experts through your Account team, or explore the resources and related documents below.

## Resources

#### Related documents:

- [AWS Cloud Financial Management](#)

#### Related examples:

- [Strategy for Efficient Cloud Cost Management](#)
- [Cost Control Blog Series #3: How to Handle Cost Shock](#)
- [A Beginner's Guide to AWS Cost Management](#)

# COST01-BP05 Report and notify on cost optimization

Configure AWS Budgets and AWS Cost Anomaly Detection to provide notifications on cost and usage against targets. Have regular meetings to analyze your workload's cost efficiency and to promote cost-aware culture.

**Level of risk exposed if this best practice is not established:** Low

## Implementation guidance

You must regularly report on cost and usage optimization within your organization. You can implement dedicated sessions to cost optimization, or include cost optimization in your regular operational reporting cycles for your workloads. Use services and tools to identify and implement cost savings opportunities. [AWS Cost Explorer](#) provides dashboards and reports. You can track your progress of cost and usage against configured budgets with [AWS Budgets Reports](#).

Use [AWS Budgets](#) to set custom budgets to track your costs and usage, and respond quickly to alerts received from email or Amazon Simple Notification Service (Amazon SNS) notifications if you exceed your threshold. [Set your preferred budget](#) period to daily, monthly, quarterly, or annually, and create specific budget limits to stay informed on how actual or forecasted costs and usage progress toward your budget threshold. You can also set up [alerts](#) and [actions](#) against those alerts to run automatically, or through an approval process when a budget target is exceeded.

Implement notifications on cost and usage to ensure that changes in cost and usage can be acted upon quickly if they are unexpected. [AWS Cost Anomaly Detection](#) allows you to reduce cost surprises and enhance control without slowing innovation. AWS Cost Anomaly Detection identifies anomalous spend and root causes, which helps to reduce the risk of billing surprises. With three simple steps, you can create your own contextualized monitor and receive alerts when any anomalous spend is detected.

You can also use [Amazon QuickSight](#) with AWS Cost and Usage Report (CUR) data, to provide highly customized reporting with more granular data. Amazon QuickSight allows you to schedule reports and receive periodic Cost Report emails for historical cost and usage, or cost-saving opportunities.

Use [AWS Trusted Advisor](#), which provides guidance to verify whether provisioned resources are aligned with AWS best practices for cost optimization.

Periodically create reports containing a highlight of Savings Plans, Reserved Instances and Amazon Elastic Compute Cloud (Amazon EC2) rightsizing recommendations from AWS Cost Explorer to start reducing the cost associated with steady-state workloads, idle, and underutilized resources. Identify and recoup spend associated with cloud waste for resources that are deployed. Cloud waste occurs when incorrectly-sized resources are created, or different usage patterns are observed instead what is expected. Follow AWS best practices to reduce your waste and [optimize and save](#) your cloud costs.

Generate reports regularly for better purchasing options for your resources to drive down unit costs for your workloads. Purchasing options such as Savings Plans, Reserved Instances, or Amazon EC2 Spot Instances offer the deepest cost savings for fault-tolerant workloads and allow stakeholders (business owners, finance and tech teams) to be part of these commitment discussions.

Share the reports that contain opportunities or new release announcements that may help you to reduce total cost of ownership (TCO) of the cloud. Adopt new services, Regions, features, solutions, or new ways to achieve further cost reductions.

### Implementation steps

- **Configure AWS Budgets:** Configure AWS Budgets on all accounts for your workload. Set a budget for the overall account spend, and a budget for the workload by using tags.

- [Well-Architected Labs: Cost and Governance Usage](#)
- **Report on cost optimization:** Set up a regular cycle to discuss and analyze the efficiency of the workload. Using the metrics established, report on the metrics achieved and the cost of achieving them. Identify and fix any negative trends, and identify positive trends that you can promote across your organization. Reporting should involve representatives from the application teams and owners, finance, and management.
- [Well-Architected Labs: Visualization](#)

## Resources

### Related documents:

- [AWS Cost Explorer](#)
- [AWS Trusted Advisor](#)
- [AWS Budgets](#)
- [AWS Budgets Best Practices](#)
- [Amazon CloudWatch](#)
- [AWS CloudTrail](#)
- [Amazon S3 Analytics](#)
- [AWS Cost and Usage Report](#)

### Related examples:

- [Well-Architected Labs: Cost and Governance Usage](#)
- [Well-Architected Labs: Visualization](#)
- [Key ways to start optimizing your AWS cloud costs](#)

## COST01-BP06 Monitor cost proactively

Implement tooling and dashboards to monitor cost proactively for the workload. Regularly review the costs with configured tools or out of the box tools, do not just look at costs and categories when you receive notifications. Monitoring and analyzing costs proactively helps to identify positive trends and allows you to promote them throughout your organization.

**Level of risk exposed if this best practice is not established:** Medium

## Implementation guidance

It is recommended to monitor cost and usage proactively within your organization, not just when there are exceptions or anomalies. Highly visible dashboards throughout your office or work environment ensure that key people have access to the information they need, and indicate the organization's focus on cost optimization. Visible dashboards allow you to actively promote successful outcomes and implement them throughout your organization.

Create a daily or frequent routine to use [AWS Cost Explorer](#) or any other dashboard such as [Amazon QuickSight](#) to see the costs and analyze proactively. Analyze AWS service usage and costs at the AWS account-level, workload-level, or specific AWS service-level with grouping and filtering, and validate whether they are expected or not. Use the hourly- and resource-level granularity and tags to filter and identify incurring costs for the top resources. You can also build your own reports with the [Cost Intelligence Dashboard](#), an [Amazon QuickSight](#) solution built by AWS Solutions Architects, and compare your budgets with the actual cost and usage.

### Implementation steps

- **Report on cost optimization:** Set up a regular cycle to discuss and analyze the efficiency of the workload. Using the metrics established, report on the metrics achieved and the cost of achieving them. Identify and fix any negative trends, and identify positive trends to promote across your organization. Reporting should involve representatives from the application teams and owners, finance, and management.
- **Create and activate daily granularity [AWS Budgets](#) for the cost and usage to take timely actions to prevent any potential cost overruns:** AWS Budgets allow you to configure alert notifications, so you stay informed if any of your budget types fall out of your pre-configured thresholds. The best way to leverage AWS Budgets is to set your expected cost and usage as your limits, so that anything above your budgets can be considered overspend.
- **Create AWS Cost Anomaly Detection for cost monitor:** [AWS Cost Anomaly Detection](#) uses advanced Machine Learning technology to identify anomalous spend and root causes, so you can quickly take action. It allows you to configure cost monitors that define spend segments you want to evaluate (for example, individual AWS services, member accounts, cost allocation tags, and cost categories), and lets you set when, where, and how you receive your alert notifications. For each monitor, attach multiple alert subscriptions for business owners and technology teams, including a name, a cost impact threshold, and alerting frequency (individual alerts, daily summary, weekly summary) for each subscription.
- **Use AWS Cost Explorer or integrate your AWS Cost and Usage Report (CUR) data with Amazon QuickSight dashboards to visualize your organization's costs:** AWS Cost Explorer has an easy-to-use interface that lets you visualize, understand, and manage your AWS costs and usage over time. The [Cost Intelligence Dashboard](#) is a customizable and accessible dashboard to help create the foundation of your own cost management and optimization tool.

## Resources

### Related documents:

- [AWS Budgets](#)
- [AWS Cost Explorer](#)
- [Daily Cost and Usage Budgets](#)
- [AWS Cost Anomaly Detection](#)

### Related examples:

- [Well-Architected Labs: Visualization](#)
- [Well-Architected Labs: Advanced Visualization](#)
- [Well-Architected Labs: Cloud Intelligence Dashboards](#)
- [Well-Architected Labs: Cost Visualization](#)
- [AWS Cost Anomaly Detection Alert with Slack](#)

## COST01-BP07 Keep up-to-date with new service releases

Consult regularly with experts or AWS Partners to consider which services and features provide lower cost. Review AWS blogs and other information sources.

**Level of risk exposed if this best practice is not established:** Medium

## Implementation guidance

AWS is constantly adding new capabilities so you can leverage the latest technologies to experiment and innovate more quickly. You may be able to implement new AWS services and features to increase cost efficiency in your workload. Regularly review [AWS Cost Management](#), the [AWS News Blog](#), the [AWS Cost Management blog](#), and [What's New with AWS](#) for information on new service and feature releases. What's New posts provide a brief overview of all AWS service, feature, and Region expansion announcements as they are released.

### Implementation steps

- **Subscribe to blogs:** Go to the AWS blogs pages and subscribe to the What's New Blog and other relevant blogs. You can sign up on the [communication preference](#) page with your email address.
- **Subscribe to AWS News:** Regularly review the [AWS News Blog](#) and [What's New with AWS](#) for information on new service and feature releases. Subscribe to the RSS feed, or with your email to follow announcements and releases.
- **Follow AWS Price Reductions:** Regular price cuts on all our services has been a standard way for AWS to pass on the economic efficiencies to our customers gained from our scale. As of April 2022, AWS has reduced prices 115 times since it was launched in 2006. If you have any pending business decisions due to price concerns, you can review them again after price reductions and new service integrations. You can learn about the previous price reductions efforts, including Amazon Elastic Compute Cloud (Amazon EC2) instances, in the [price-reduction category of the AWS News Blog](#).
- **AWS events and meetups:** Attend your local AWS summit, and any local meetups with other organizations from your local area. If you cannot attend in person, try to attend virtual events to hear more from AWS experts and other customers' business cases.
- **Meet with your account team:** Schedule a regular cadence with your account team, meet with them and discuss industry trends and AWS services. Speak with your account manager, Solutions Architect, and support team.

## Resources

### Related documents:

- [AWS Cost Management](#)
- [What's New with AWS](#)
- [AWS News Blog](#)

### Related examples:

- [Amazon EC2 – 15 Years of Optimizing and Saving Your IT Costs](#)
- [AWS News Blog - Price Reduction](#)

## COST01-BP08 Create a cost-aware culture

Implement changes or programs across your organization to create a cost-aware culture. It is recommended to start small, then as your capabilities increase and your organization's use of the cloud increases, implement large and wide ranging programs.

**Level of risk exposed if this best practice is not established:** Low



## Implementation guidance

A cost-aware culture allows you to scale cost optimization and Cloud Financial Management (financial operations, cloud center of excellence, cloud operations teams, and so on) through best practices that are performed in an organic and decentralized manner across your organization. Cost awareness allows you to create high levels of capability across your organization with minimal effort, compared to a strict top-down, centralized approach.

Creating cost awareness in cloud computing, especially for primary cost drivers in cloud computing, allows teams to understand expected outcomes of any changes in cost perspective. Teams who access the cloud environments should be aware of pricing models and the difference between traditional on-premises datacenters and cloud computing.

The main benefit of a cost-aware culture is that technology teams optimize costs proactively and continually (for example, they are considered a non-functional requirement when architecting new workloads, or making changes to existing workloads) rather than performing reactive cost optimizations as needed.

Small changes in culture can have large impacts on the efficiency of your current and future workloads. Examples of this include:

- Giving visibility and creating awareness in engineering teams to understand what they do, and what they impact in terms of cost.
- Gamifying cost and usage across your organization. This can be done through a publicly visible dashboard, or a report that compares normalized costs and usage across teams (for example, cost-per-workload and cost-per-transaction).
- Recognizing cost efficiency. Reward voluntary or unsolicited cost optimization accomplishments publicly or privately, and learn from mistakes to avoid repeating them in the future.
- Creating top-down organizational requirements for workloads to run at pre-defined budgets.
- Questioning business requirements of changes, and the cost impact of requested changes to the architecture infrastructure or workload configuration to make sure you pay only what you need.
- Making sure the change planner is aware of expected changes that have a cost impact, and that they are confirmed by the stakeholders to deliver business outcomes cost-effectively.

### Implementation steps

- **Report cloud costs to technology teams:** To raise cost awareness, and establish efficiency KPIs for finance and business stakeholders.
- **Inform stakeholders or team members about planned changes:** Create an agenda item to discuss planned changes and the cost-benefit impact on the workload during weekly change meetings.
- **Meet with your account team:** Establish a regular meeting cadence with your account team, and discuss industry trends and AWS services. Speak with your account manager, architect, and support team.
- **Share success stories:** Share success stories about cost reduction for any workload, AWS account, or organization to create a positive attitude and encouragement around cost optimization.
- **Training:** Ensure technical teams or team members are trained for awareness of resource costs on AWS Cloud.
- **AWS events and meetups:** Attend local AWS summits, and any local meetups with other organizations from your local area.
- **Subscribe to blogs:** Go to the AWS blogs pages and subscribe to the [What's New Blog](#) and other relevant blogs to follow new releases, implementations, examples, and changes shared by AWS.



## Resources

### Related documents:

- [AWS Blog](#)
- [AWS Cost Management](#)
- [AWS News Blog](#)

### Related examples:

- [AWS Cloud Financial Management](#)
- [AWS Well-Architected Labs: Cloud Financial Management](#)

## COST01-BP09 Quantify business value from cost optimization

Quantifying business value from cost optimization allows you to understand the entire set of benefits to your organization. Because cost optimization is a necessary investment, quantifying business value allows you to explain the return on investment to stakeholders. Quantifying business value can help you gain more buy-in from stakeholders on future cost optimization investments, and provides a framework to measure the outcomes for your organization's cost optimization activities.

**Level of risk exposed if this best practice is not established:** Medium

## Implementation guidance

In addition to reporting savings from cost optimization, it is recommended that you quantify the additional value delivered. Cost optimization benefits are typically quantified in terms of lower costs per business outcome. For example, you can quantify On-Demand Amazon Elastic Compute Cloud(Amazon EC2) cost savings when you purchase Savings Plans, which reduce cost and maintain workload output levels. You can quantify cost reductions in AWS spending when idle Amazon EC2 instances are terminated, or unattached Amazon Elastic Block Store (Amazon EBS) volumes are deleted.

The benefits from cost optimization, however, go above and beyond cost reduction or avoidance. Consider capturing additional data to measure efficiency improvements and business value.

### Implementation steps

- **Executing cost optimization best practices:** For example, resource lifecycle management reduces infrastructure and operational costs and creates time and unexpected budget for experimentation. This increases organization agility and uncovers new opportunities for revenue generation.
- **Implementing automation:** For example, Auto Scaling, which ensures elasticity at minimal effort, and increases staff productivity by eliminating manual capacity planning work. For more details on operational resiliency, refer to the [Well-Architected Reliability Pillar whitepaper](#).
- **Forecasting future AWS costs:** Forecasting helps finance stakeholders to set expectations with other internal and external organization stakeholders, and helps improve your organization's financial predictability. AWS Cost Explorer can be used to perform forecasting for your cost and usage.

## Resources

### Related documents:

- [AWS Blog](#)
- [AWS Cost Management](#)
- [AWS News Blog](#)
- [Well-Architected Reliability Pillar whitepaper](#)
- [AWS Cost Explorer](#)

# Expenditure and usage awareness

Understanding your organization's costs and drivers is critical for managing your cost and usage effectively, and identifying cost-reduction opportunities. Organizations typically operate multiple workloads run by multiple teams. These teams can be in different organization units, each with its own revenue stream. The capability to attribute resource costs to the workloads, individual organization, or product owners drives efficient usage behavior and helps reduce waste. Accurate cost and usage monitoring allows you to understand how profitable organization units and products are, and allows you to make more informed decisions about where to allocate resources within your organization. Awareness of usage at all levels in the organization is key to driving change, as change in usage drives changes in cost.

Consider taking a multi-faceted approach to becoming aware of your usage and expenditures. Your team must gather data, analyze, and then report. Key factors to consider include:

## Topics

- [Governance \(p. 23\)](#)
- [Monitor cost and usage \(p. 33\)](#)
- [Decommission resources \(p. 42\)](#)

## Governance

To manage your costs in the cloud, you must manage your usage through the following governance areas:

### Best practices

- [COST02-BP01 Develop policies based on your organization requirements \(p. 23\)](#)
- [COST02-BP02 Implement goals and targets \(p. 25\)](#)
- [COST02-BP03 Implement an account structure \(p. 26\)](#)
- [COST02-BP04 Implement groups and roles \(p. 30\)](#)
- [COST02-BP05 Implement cost controls \(p. 31\)](#)
- [COST02-BP06 Track project lifecycle \(p. 32\)](#)

## COST02-BP01 Develop policies based on your organization requirements

Develop policies that define how resources are managed by your organization. Policies should cover cost aspects of resources and workloads, including creation, modification, and decommission over the resource lifetime.

**Level of risk exposed if this best practice is not established:** High

### Implementation guidance

Understanding your organization's costs and drivers is critical for managing your cost and usage effectively, and identifying cost-reduction opportunities. Organizations typically operate multiple

workloads run by multiple teams. These teams can be in different organization units, each with its own revenue stream. The capability to attribute resource costs to the workloads, individual organization, or product owners drives efficient usage behaviour and helps reduce waste. Accurate cost and usage monitoring allows you to understand how profitable organization units and products are, and allows you to make more informed decisions about where to allocate resources within your organization. Awareness of usage at all levels in the organization is key to driving change, as change in usage drives changes in cost. Consider taking a multi-faceted approach to becoming aware of your usage and expenditures.

The first step in performing governance is to use your organization's requirements to develop policies for your cloud usage. These policies define how your organization uses the cloud and how resources are managed. Policies should cover all aspects of resources and workloads that relate to cost or usage, including creation, modification, and decommission over the resource's lifetime. Verify that policies and procedures are followed and implemented for any change in a cloud environment. During your IT change management meetings, raise questions to find out the cost impact of planned changes whether increasing or decreasing, the business justification, and the expected outcome.

Policies should be simple so that they are easily understood and can be implemented effectively throughout the organization. Start with broad, high-level policies, such as which geographic Region to use or times of the day that resources should be running. Gradually refine the policies for the various organizational units and workloads. Common policies include which services and features can be used (for example, lower performance storage in test and development environments), which types of resources can be used by different groups (for example, the largest size of resource in a development account is medium), and how long these resources will be in use (whether temporary, short term, or for a specific period of time).

### Implementation steps

- **Meet with team members:** To develop policies, get all team members from your organization to specify their requirements and document them accordingly. Take an iterative approach by starting broadly and continually refine down to the smallest units at each step. Team members include those with direct interest in the workload, such as organization units or application owners, as well as supporting groups, such as security and finance teams.
- **Get confirmation:** Make sure teams agree on policies who can access and deploy to the AWS Cloud. Make sure they follow your organization's policies and confirm that their resource creations align with the agreed policies and procedures.
- **Create onboarding training sessions:** Ask new organization members to complete onboarding training courses to create cost awareness and organization requirements. They may assume different policies from their previous experience or not think of them at all.
- **Define locations for your workload:** Define where your workload operates, including the country and the area within the country. This information is used for mapping to AWS Regions and Availability Zones.
- **Define and group services and resources:** Define the services that the workloads require. For each service, specify the types, the size, and the number of resources required. Define groups for the resources by function, such as application servers or database storage. Resources can belong to multiple groups.
- **Define and group the users by function:** Define the users that interact with the workload, focusing on what they do and how they use the workload, not on who they are or their position in the organization. Group similar users or functions together. You can use the AWS managed policies as a guide.
- **Define the actions:** Using the locations, resources, and users identified previously, define the actions that are required by each to achieve the workload outcomes over its life time (development, operation, and decommission). Identify the actions based on the groups, not the individual elements in the groups, in each location. Start broadly with read or write, then refine down to specific actions to each service.
- **Define the review period:** Workloads and organizational requirements can change over time. Define the workload review schedule to ensure it remains aligned with organizational priorities.

- **Document the policies:** Verify the policies that have been defined are accessible as required by your organization. These policies are used to implement, maintain, and audit access of your environments.

## Resources

### Related documents:

- [Change Management in the Cloud](#)
- [AWS Managed Policies for Job Functions](#)
- [AWS multiple account billing strategy](#)
- [Actions, Resources, and Condition Keys for AWS Services](#)
- [AWS Management and Governance](#)
- [Control access to AWS Regions using IAM policies](#)
- [Global Infrastructures Regions and AZs](#)

### Related videos:

- [AWS Management and Governance at Scale](#)

### Related examples:

- [VMware - What Are Cloud Policies?](#)

## COST02-BP02 Implement goals and targets

Implement both cost and usage goals and targets for your workload. Goals provide direction to your organization on expected outcomes, and targets provide specific measurable outcomes to be achieved for your workloads.

**Level of risk exposed if this best practice is not established:** High

## Implementation guidance

Develop cost and usage goals and targets for your organization. Setting realistic goals can help you to continue to seek efficiency which is so important to ongoing business operations. Goals provide guidance and direction to your organization on expected outcomes. Targets provide specific measurable outcomes to be achieved. In short, a goal is the direction you want to go and target is how far in that direction and when that goal should be achieved (using guidance of specific, measurable assignable, realistic, and timely, or SMART). An example of a goal is that platform usage should increase significantly, with only a minor (non-linear) increase in cost. An example target is a 20% increase in platform usage, with less than a 5% increase in costs. Another common goal is that workloads need to be more efficient every 6 months. The accompanying target would be that the cost per output of the workload needs to decrease by 5% every 6 months.

A common goal for cloud workloads is to increase workload efficiency, which is to decrease the cost per business outcome of the workload over time. It is recommended to implement this goal for all workloads, and also set a target such as a 5% increase in efficiency every 6-12 months. This can be achieved in the cloud through building capability in cost optimization, and through the release of new services and features.

### Implementation steps

- **Define expected usage levels:** To begin, focus on usage levels. Engage with the application owners, marketing, and greater business teams to understand what the expected usage levels will be for the

workload. How will customer demand change over time, and will there be any changes due to seasonal increases or marketing campaigns?

- **Define workload resourcing and costs:** With usage levels defined, quantify the changes in workload resources required to meet these usage levels. You may need to increase the size or number of resources for a workload component, increase data transfer, or change workload components to a different service at a specific level. Specify what the costs will be at each of these major points, and what the changes in cost will be when there are changes in usage.
- **Define business goals:** Taking the output from the expected changes in usage and cost, combine this with expected changes in technology, or any programs that you are running, and develop goals for the workload. Goals must address usage, cost and the relationship between the two. Goals must be simple, high level, and help people understand what the business expects in terms of outcomes (such as making sure unused resources are kept below certain cost level). You don't need to define goals for each unused resource type or define costs that cause losses for goals and targets. Verify that there are organizational programs (for example, capability building like training and education) if there are expected changes in cost without changes in usage.
- **Define targets:** For each of the defined goals specify a measurable target. If the goal is to increase efficiency in the workload, the target will quantify the amount of improvement (typically in business outputs for each dollar spent) and when it will be delivered. For example, if you set a goal of minimizing waste due to over-provisioning, then your target can be waste due to compute over-provisioning in the first tier of production workloads should not exceed 10% of tier compute cost, and waste due to compute over-provisioning in the second tier of production workloads should not exceed 5% of tier compute cost.

## Resources

### Related documents:

- [AWS managed policies for job functions](#)
- [AWS multi-account strategy for your AWS Control Tower landing zone](#)
- [Control access to AWS Regions using IAM policies](#)
- [SMART Goals](#)

### Related videos:

- [Well-Architected Labs: Goals and Targets \(Level 100\)](#)

### Related examples:

- [Well-Architected Labs: Decommission resources \(Goals and Targets\)](#)
- [Well-Architected Labs: Resource Type, Size, and Number \(Goals and Targets\)](#)

## COST02-BP03 Implement an account structure

Implement a structure of accounts that maps to your organization. This assists in allocating and managing costs throughout your organization.

**Level of risk exposed if this best practice is not established:** High

## Implementation guidance

AWS Organizations allows you to create multiple AWS accounts which can help you centrally govern your environment as you scale your workloads on AWS. You can model your organizational hierarchy

by grouping AWS accounts in organizational unit (OU) structure and creating multiple AWS accounts under each OU. To create an account structure, you need to decide which of your AWS accounts will be the management account first. After that, you can create new AWS accounts or select existing accounts as member accounts based on your designed account structure by following [management account best practices](#) and [member account best practices](#).

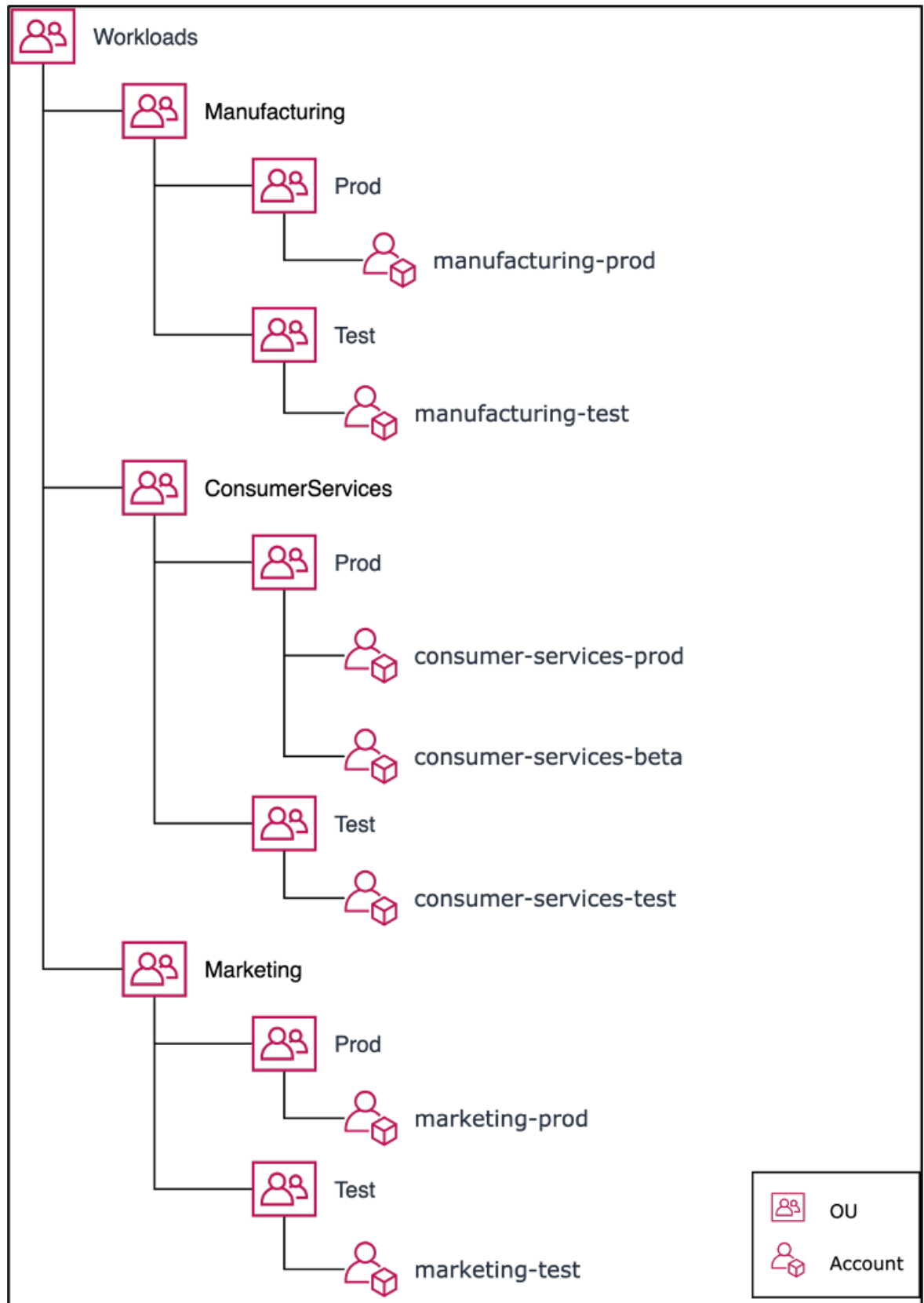
It is advised to always have at least one management account with one member account linked to it, regardless of your organization size or usage. All workload resources should reside only within member accounts and no resource should be created in management account. There is no one size fits all answer for how many AWS accounts you should have. Assess your current and future operational and cost models to ensure that the structure of your AWS accounts reflects your organization's goals. Some companies create multiple AWS accounts for business reasons, for example:

- Administrative or fiscal and billing isolation is required between organization units, cost centers, or specific workloads.
- AWS service limits are set to be specific to particular workloads.
- There is a requirement for isolation and separation between workloads and resources.

Within [AWS Organizations](#), [consolidated billing](#) creates the construct between one or more member accounts and the management account. Member accounts allow you to isolate and distinguish your cost and usage by groups. A common practice is to have separate member accounts for each organization unit (such as finance, marketing, and sales), or for each environment lifecycle (such as development, testing and production), or for each workload (workload a, b, and c), and then aggregate these linked accounts using consolidated billing.

Consolidated billing allows you to consolidate payment for multiple member AWS accounts under a single management account, while still providing visibility for each linked account's activity. As costs and usage are aggregated in the management account, this allows you to maximize your service volume discounts, and maximize the use of your commitment discounts (Savings Plans and Reserved Instances) to achieve the highest discounts.

The following diagram shows how you can use AWS Organizations with organizational units (OU) to group multiple accounts, and place multiple AWS accounts under each OU. It is recommended to use OUs for various use cases and workloads which provides patterns for organizing accounts.





*Example of grouping multiple AWS accounts under organizational units.*

[AWS Control Tower](#) can quickly set up and configure multiple AWS accounts, ensuring that governance is aligned with your organization's requirements.

### Implementation steps

- **Define separation requirements:** Requirements for separation are a combination of multiple factors, including security, reliability, and financial constructs. Work through each factor in order and specify whether the workload or workload environment should be separate from other workloads. Security promotes adherence to access and data requirements. Reliability manages limits so that environments and workloads do not impact others. Review the security and reliability pillars of the Well-Architected Framework periodically and follow the provided best practices. Financial constructs create strict financial separation (different cost center, workload ownerships and accountability). Common examples of separation are production and test workloads being run in separate accounts, or using a separate account so that the invoice and billing data can be provided to the individual business units or departments in the organization or stakeholder who owns the account.
- **Define grouping requirements:** Requirements for grouping do not override the separation requirements, but are used to assist management. Group together similar environments or workloads that do not require separation. An example of this is grouping multiple test or development environments from one or more workloads together.
- **Define account structure:** Using these separations and groupings, specify an account for each group and maintain separation requirements. These accounts are your member or linked accounts. By grouping these member accounts under a single management or payer account, you combine usage, which allows for greater volume discounts across all accounts, which provides a single bill for all accounts. It's possible to separate billing data and provide each member account with an individual view of their billing data. If a member account must not have its usage or billing data visible to any other account, or if a separate bill from AWS is required, define multiple management or payer accounts. In this case, each member account has its own management or payer account. Resources should always be placed in member or linked accounts. The management or payer accounts should only be used for management.

## Resources

### Related documents:

- [Using Cost Allocation Tags](#)
- [AWS managed policies for job functions](#)
- [AWS multiple account billing strategy](#)
- [Control access to AWS Regions using IAM policies](#)
- [AWS Control Tower](#)
- [AWS Organizations](#)
- Best practices for [management accounts](#) and [member accounts](#)
- [Organizing Your AWS Environment Using Multiple Accounts](#)
- [Turning on shared reserved instances and Savings Plans discounts](#)
- [Consolidated billing](#)
- [Consolidated billing](#)

### Related examples:

- [Splitting the CUR and Sharing Access](#)

**Related videos:**

- [Introducing AWS Organizations](#)
- [Set Up a Multi-Account AWS Environment that Uses Best Practices for AWS Organizations](#)

**Related examples:**

- [Well-Architected Labs: Create an AWS Organization \(Level 100\)](#)
- [Splitting the AWS Cost and Usage Report and Sharing Access](#)
- [Defining an AWS Multi-Account Strategy for telecommunications companies](#)
- [Best Practices for Optimizing AWS accounts](#)
- [Best Practices for Organizational Units with AWS Organizations](#)

## COST02-BP04 Implement groups and roles

Implement groups and roles that align to your policies and control who can create, modify, or decommission instances and resources in each group. For example, implement development, test, and production groups. This applies to AWS services and third-party solutions.

**Level of risk exposed if this best practice is not established:** Low

### Implementation guidance

After you develop policies, you can create logical groups and roles of users within your organization. This allows you to assign permissions and control usage. Begin with high-level groupings of people. Typically this aligns with organizational units and job roles (for example, systems administrator in the IT Department, or financial controller). The groups join people that do similar tasks and need similar access. Roles define what a group must do. For example, a systems administrator in IT requires access to create all resources, but an analytics team member only needs to create analytics resources.

**Implementation steps**

- **Implement groups:** Using the groups of users defined in your organizational policies, implement the corresponding groups, if necessary. Refer to the security pillar for best practices on users, groups, and authentication.
- **Implement roles and policies:** Using the actions defined in your organizational policies, create the required roles and access policies. Refer to the security pillar for best practices on roles and policies.

### Resources

**Related documents:**

- [AWS managed policies for job functions](#)
- [AWS multiple account billing strategy](#)
- [Control access to AWS Regions using IAM policies](#)
- [Well-Architected Security Pillar](#)

**Related examples:**

- [Well-Architected Lab Basic Identity and Access](#)

## COST02-BP05 Implement cost controls

Implement controls based on organization policies and defined groups and roles. These certify that costs are only incurred as defined by organization requirements such as control access to regions or resource types.

**Level of risk exposed if this best practice is not established:** Medium

### Implementation guidance

A common first step in implementing cost controls is to set up notifications when cost or usage events occur outside of policies. You can act quickly and verify if corrective action is required without restricting or negatively impacting workloads or new activity. After you know the workload and environment limits, you can enforce governance. [AWS Budgets](#) allows you to set notifications and define monthly budgets for your AWS costs, usage, and commitment discounts (Savings Plans and Reserved Instances). You can create budgets at an aggregate cost level (for example, all costs), or at a more granular level where you include only specific dimensions such as linked accounts, services, tags, or Availability Zones.

Once you set up your budget limits with AWS Budgets, use [AWS Cost Anomaly Detection](#) to reduce your unexpected cost. AWS Cost Anomaly Detection is a cost management services that uses machine learning to continually monitor your cost and usage to detect unusual spends. It helps you identify anomalous spend and root causes, so you can quickly take action. First, create a cost monitor in AWS Cost Anomaly Detection, then choose your alerting preference by setting up a dollar threshold (such as an alert on anomalies with impact greater than \$1,000). Once you receive alerts, you can analyze the root cause behind the anomaly and impact on your costs. You can also monitor and perform your own anomaly analysis in AWS Cost Explorer.

Enforce governance policies in AWS through [AWS Identity and Access Management](#) and [AWS Organizations Service Control Policies \(SCP\)](#). IAM allows you to securely manage access to AWS services and resources. Using IAM, you can control who can create or manage AWS resources, the type of resources that can be created, and where they can be created. This minimizes the possibility of resources being created outside of the defined policy. Use the roles and groups created previously and assign [IAM policies](#) to enforce the correct usage. SCP offers central control over the maximum available permissions for all accounts in your organization, keeping your accounts stay within your access control guidelines. SCPs are available only in an organization that has all features turned on, and you can configure the SCPs to either deny or allow actions for member accounts by default. For more details on implementing access management, see the [Well-Architected Security Pillar whitepaper](#).

Governance can also be implemented through management of [AWS service quotas](#). By ensuring service quotas are set with minimum overhead and accurately maintained, you can minimize resource creation outside of your organization's requirements. To achieve this, you must understand how quickly your requirements can change, understand projects in progress (both creation and decommission of resources), and factor in how fast quota changes can be implemented. [Service quotas](#) can be used to increase your quotas when required.

### Implementation steps

- **Implement notifications on spend:** Using your defined organization policies, create [AWS Budgets](#) to notify you when spending is outside of your policies. Configure multiple cost budgets, one for each account, which notify you about overall account spending. Configure additional cost budgets within each account for smaller units within the account. These units vary depending on your account structure. Some common examples are AWS Regions, workloads (using tags), or AWS services. Configure an email distribution list as the recipient for notifications, and not an individual's email account. You can configure an actual budget for when an amount is exceeded, or use a forecasted budget for notifying on forecasted usage. You can also preconfigure AWS Budget Actions that can enforce specific IAM or SCP policies, or stop target Amazon EC2 or Amazon RDS instances. Budget Actions can be started automatically or require workflow approval.

- **Implement notifications on anomalous spend:** Use [AWS Cost Anomaly Detection](#) to reduce your surprise costs in your organization and analyze root cause of potential anomalous spend. Once you create cost monitor to identify unusual spend at your specified granularity and configure notifications in AWS Cost Anomaly Detection, it sends you alert when unusual spend is detected. This will allow you to analyze root cause behind the anomaly and understand the impact on your cost. Use AWS Cost Categories while configuring AWS Cost Anomaly Detection to identify which project team or business unit team can analyze the root cause of the unexpected cost and take timely necessary actions.
- **Implement controls on usage:** Using your defined organization policies, implement IAM policies and roles to specify which actions users can perform and which actions they cannot. Multiple organizational policies may be included in an AWS policy. In the same way that you defined policies, start broadly and then apply more granular controls at each step. Service limits are also an effective control on usage. Implement the correct service limits on all your accounts.

## Resources

### Related documents:

- [AWS managed policies for job functions](#)
- [AWS multiple account billing strategy](#)
- [Control access to AWS Regions using IAM policies](#)
- [AWS Budgets](#)
- [AWS Cost Anomaly Detection](#)
- [Control Your AWS Costs](#)

### Related videos:

- [How can I use AWS Budgets to track my spending and usage](#)

### Related examples:

- [Example IAM access management policies](#)
- [Example service control policies](#)
- [AWS Budgets Actions](#)
- [Create IAM Policy to control access to Amazon EC2 resources using Tags](#)
- [Restrict the access of IAM Identity to specific Amazon EC2 resources](#)
- [Create an IAM Policy to restrict Amazon EC2 usage by family](#)
- [Well-Architected Labs: Cost and Usage Governance \(Level 100\)](#)
- [Well-Architected Labs: Cost and Usage Governance \(Level 200\)](#)
- [Slack integrations for Cost Anomaly Detection using AWS Chatbot](#)

## COST02-BP06 Track project lifecycle

Track, measure, and audit the lifecycle of projects, teams, and environments to avoid using and paying for unnecessary resources.

**Level of risk exposed if this best practice is not established:** Low

## Implementation guidance

Ensure that you track the entire lifecycle of the workload. This ensures that when workloads or workload components are no longer required, they can be decommissioned or modified. This is especially useful

when you release new services or features. The existing workloads and components may appear to be in use, but should be decommissioned to redirect customers to the new service. Notice previous stages of workloads — after a workload is in production, previous environments can be decommissioned or greatly reduced in capacity until they are required again.

AWS provides a number of management and governance services you can use for entity lifecycle tracking. You can use [AWS Config](#) or [AWS Systems Manager](#) to provide a detailed inventory of your AWS resources and configuration. It is recommended that you integrate with your existing project or asset management systems to keep track of active projects and products within your organization. Combining your current system with the rich set of events and metrics provided by AWS allows you to build a view of significant lifecycle events and proactively manage resources to reduce unnecessary costs.

Refer to the [Well-Architected Operational Excellence Pillar whitepaper](#) for more details on implementing entity lifecycle tracking.

### Implementation steps

- **Perform workload reviews:** As defined by your organizational policies, audit your existing projects. The amount of effort spent in the audit should be proportional to the approximate risk, value, or cost to the organization. Key areas to include in the audit would be risk to the organization of an incident or outage, value, or contribution to the organization (measured in revenue or brand reputation), cost of the workload (measured as total cost of resources and operational costs), and usage of the workload (measured in number of organization outcomes per unit of time). If these areas change over the lifecycle, adjustments to the workload are required, such as full or partial decommissioning.

## Resources

### Related documents:

- [AWS Config](#)
- [AWS Systems Manager](#)
- [AWS managed policies for job functions](#)
- [AWS multiple account billing strategy](#)
- [Control access to AWS Regions using IAM policies](#)

# Monitor cost and usage

Enable teams to take action on their cost and usage through detailed visibility into the workload. Cost optimization begins with a granular understanding of the breakdown in cost and usage, the ability to model and forecast future spend, usage, and features, and the implementation of sufficient mechanisms to align cost and usage to your organization's objectives. The following are required areas for monitoring your cost and usage:

### Best practices

- [COST03-BP01 Configure detailed information sources \(p. 34\)](#)
- [COST03-BP02 Add organization information to cost and usage \(p. 35\)](#)
- [COST03-BP03 Identify cost attribution categories \(p. 36\)](#)
- [COST03-BP04 Establish organization metrics \(p. 38\)](#)
- [COST03-BP05 Configure billing and cost management tools \(p. 39\)](#)
- [COST03-BP06 Allocate costs based on workload metrics \(p. 41\)](#)

## COST03-BP01 Configure detailed information sources

Configure the AWS Cost and Usage Report, and Cost Explorer hourly granularity, to provide detailed cost and usage information. Configure your workload to have log entries for every delivered business outcome.

**Level of risk exposed if this best practice is not established:** High

### Implementation guidance

Enable hourly granularity in AWS Cost Explorer and create a [AWS Cost and Usage Report \(CUR\)](#). These data sources provide the most accurate view of cost and usage across your entire organization. The CUR provides daily or hourly usage granularity, rates, costs, and usage attributes for all chargeable AWS services. All possible dimensions are in the CUR including: tagging, location, resource attributes, and account IDs.

Configure your CUR with the following customizations:

- Include resource IDs
- Automatically refresh the CUR
- Hourly granularity
- **Versioning:** Overwrite existing report
- **Data integration:** Amazon Athena (Parquet format and compression)

Use [AWS Glue](#) to prepare the data for analysis, and use [Amazon Athena](#) to perform data analysis, using SQL to query the data. You can also use [Amazon QuickSight](#) to build custom and complex visualizations and distribute them throughout your organization.

### Implementation steps

- **Configure the cost and usage report:** Using the billing console, configure at least one cost and usage report. Configure a report with hourly granularity that includes all identifiers and resource IDs. You can also create other reports with different granularities to provide higher-level summary information.
- **Configure hourly granularity in Cost Explorer:** Using the billing console, turn on Hourly and Resource Level Data.

#### Note

There will be associated costs with activating this feature. For details, refer to the pricing.

- **Configure application logging:** Verify that your application logs each business outcome that it delivers so it can be tracked and measured. Ensure that the granularity of this data is at least hourly so it matches with the cost and usage data. Refer to the [Well-Architected Operational Excellence Pillar](#) for more detail on logging and monitoring.

## Resources

### Related documents:

- [AWS Account Setup](#)
- [AWS Cost and Usage Report \(CUR\)](#)
- [AWS Glue](#)

- [Amazon QuickSight](#)
- [AWS Cost Management Pricing](#)
- [Tagging AWS resources](#)
- [Analyzing your costs with AWS Budgets](#)
- [Analyzing your costs with Cost Explorer](#)
- [Managing AWS Cost and Usage Reports](#)
- [Well-Architected Operational Excellence Pillar](#)

**Related examples:**

- [AWS Account Setup](#)

## COST03-BP02 Add organization information to cost and usage

Define a tagging schema based on your organization, workload attributes, and cost allocation categories so that you can filter and search for resources or monitor cost and usage in cost management tools. Implement consistent tagging across all resources where possible by purpose, team, environment, or other criteria relevant to your business.

**Level of risk exposed if this best practice is not established:** Medium

### Implementation guidance

Implement [tagging in AWS](#) to add organization information to your resources, which will then be added to your cost and usage information. A tag is a key-value pair — the key is defined and must be unique across your organization, and the value is unique to a group of resources. An example of a key-value pair is the key is `Environment`, with a value of `Production`. All resources in the production environment will have this key-value pair. Tagging allows you categorize and track your costs with meaningful, relevant organization information. You can apply tags that represent organization categories (such as cost centers, application names, projects, or owners), and identify workloads and characteristics of workloads (such as test or production) to attribute your costs and usage throughout your organization.

When you apply tags to your AWS resources (such as Amazon Elastic Compute Cloud instances or Amazon Simple Storage Service buckets) and activate the tags, AWS adds this information to your Cost and Usage Reports. You can run reports and perform analysis on tagged and untagged resources to allow greater compliance with internal cost management policies and ensure accurate attribution.

Creating and implementing an AWS tagging standard across your organization's accounts helps you manage and govern your AWS environments in a consistent and uniform manner. Use [Tag Policies](#) in AWS Organizations to define rules for how tags can be used on AWS resources in your accounts in AWS Organizations. Tag Policies allow you to easily adopt a standardized approach for tagging AWS resources

[AWS Tag Editor](#) allows you to add, delete, and manage tags of multiple resources. With Tag Editor, you search for the resources that you want to tag, and then manage tags for the resources in your search results.

[AWS Cost Categories](#) allows you to assign organization meaning to your costs, without requiring tags on resources. You can map your cost and usage information to unique internal organization structures. You define category rules to map and categorize costs using billing dimensions, such as accounts and tags. This provides another level of management capability in addition to tagging. You can also map specific accounts and tags to multiple projects.

### Implementation steps

- **Define a tagging schema:** Gather all stakeholders from across your business to define a schema. This typically includes people in technical, financial, and management roles. Define a list of tags that all resources must have, as well as a list of tags that resources should have. Verify that the tag names and values are consistent across your organization.
- **Tag resources:** Using your defined cost attribution categories, [place tags](#) on all resources in your workloads according to the categories. Use tools such as the CLI, Tag Editor, or AWS Systems Manager to increase efficiency.
- **Implement AWS Cost Categories:** You can create [Cost Categories](#) without implementing tagging. Cost categories use the existing cost and usage dimensions. Create category rules from your schema and implement them into cost categories.
- **Automate tagging:** To verify that you maintain high levels of tagging across all resources, automate tagging so that resources are automatically tagged when they are created. Use services such as [AWS CloudFormation](#) to verify that resources are tagged when created. You can also create a custom solution to [tag automatically](#) using Lambda functions or use a microservice that scans the workload periodically and removes any resources that are not tagged, which is ideal for test and development environments.
- **Monitor and report on tagging:** To verify that you maintain high levels of tagging across your organization, report and monitor the tags across your workloads. You can use [AWS Cost Explorer](#) to view the cost of tagged and untagged resources, or use services such as [Tag Editor](#). Regularly review the number of untagged resources and take action to add tags until you reach the desired level of tagging.

## Resources

### Related documents:

- [Tagging Best Practices](#)
- [AWS CloudFormation Resource Tag](#)
- [AWS Cost Categories](#)
- [Tagging AWS resources](#)
- [Analyzing your costs with AWS Budgets](#)
- [Analyzing your costs with Cost Explorer](#)
- [Managing AWS Cost and Usage Reports](#)

### Related videos:

- [How can I tag my AWS resources to divide up my bill by cost center or project](#)
- [Tagging AWS Resources](#)

### Related examples:

- [Automatically tag new AWS resources based on identity or role](#)

## COST03-BP03 Identify cost attribution categories

Identify organization categories that could be used to allocate cost within your organization.

**Level of risk exposed if this best practice is not established:** High

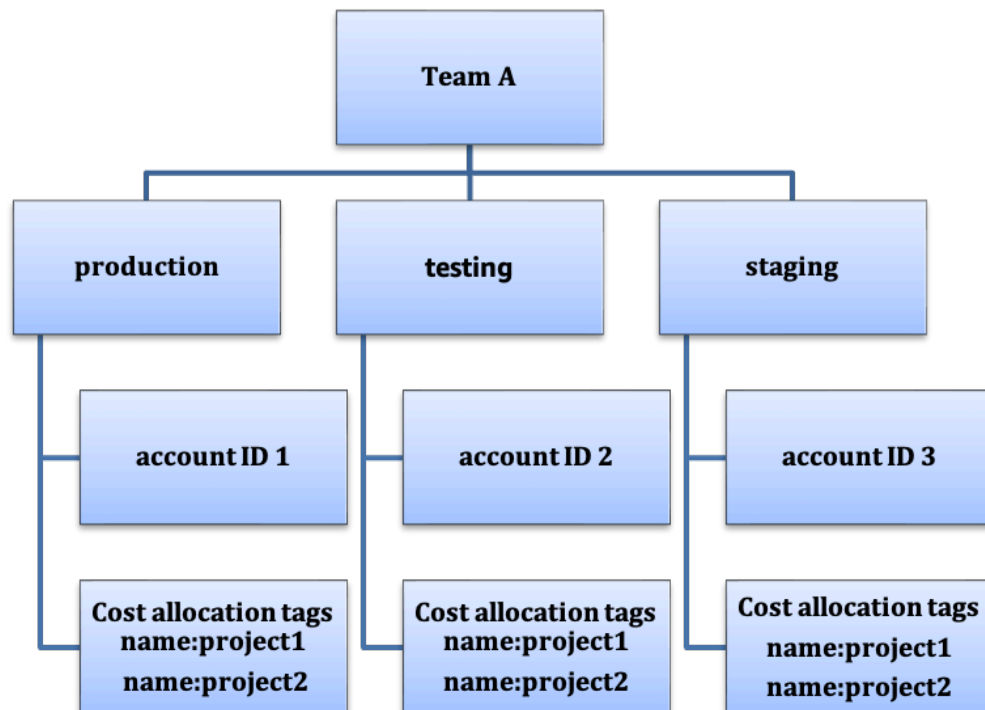


## Implementation guidance

Work with your finance team and other relevant stakeholders to understand the requirements of how costs must be allocated within your organization. Workload costs must be allocated throughout the entire lifecycle, including development, testing, production, and decommissioning. Understand how the costs incurred for learning, staff development, and idea creation are attributed in the organization. This can be helpful to correctly allocate accounts used for this purpose to training and development budgets, instead of generic IT cost budgets.

After defining your cost attribution categories with your stakeholders in your organization, use [AWS Cost Categories](#) to group your cost and usage information into meaningful categories in the AWS Cloud such as cost for specific project or AWS accounts for departments or business units. You can create custom categories and map your cost and usage information into these categories based on rules you define using various dimensions such as account, tag, service, charge type, and even other cost categories. Once cost categories are set up, you will be able to view your cost and usage information by these categories allowing your organization to make better strategic and purchasing decisions. These categories will be visible in AWS Cost Explorer, AWS Budgets, and AWS Cost and Usage Report as well.

As an example, the following diagram shows you how can you group your costs and usage information in your organization such as having multiple teams (cost category) having multiple environments (rules) and each environment having multiple resources or assets (dimensions).



*Cost and usage organization chart.*

### Implementation steps

- **Define your organization categories:** Meet with stakeholders to define categories that reflect your organization's structure and requirements. These will directly map to the structure of existing financial categories, such as business unit, budget, cost center, or department. Look at the outcomes the cloud delivers for your business, such as training or education, as these are also organization categories. Multiple categories can be assigned to a resource, and a resource can be in multiple different categories, so define as many categories as needed.

- **Define your functional categories:** Meet with stakeholders to define categories that reflect the functions that you have within your business. This may be the workload or application names, and the type of environment, such as production, testing, or development. Multiple categories can be assigned to a resource, and a resource can be in multiple different categories, so define as many categories as needed so that you can [manage your costs](#) within the categorized structure using AWS Cost Categories.
- **Define AWS Cost Categories:** You can [create cost categories](#) to organize your cost and usage information. Use [AWS Cost Categories](#) to map your AWS costs and usage into meaningful categories. With cost categories, you can organize your costs using a rule-based engine. The rules that you configure organize your costs into categories. Within these rules, you can filter with using multiple dimensions for each category such as specific AWS accounts, specific AWS services, or specific charge types. You can then use these categories across multiple products in the [AWS Billing and Cost Management console](#). This includes AWS Cost Explorer, AWS Budgets, AWS Cost and Usage Report, and AWS Cost Anomaly Detection. You can create groupings of costs using cost categories as well. After you create the cost categories (allowing up to 24 hours after creating a cost category for your usage records to be updated with values), they appear in [AWS Cost Explorer](#), [AWS Budgets](#), [AWS Cost and Usage Report](#), and [AWS Cost Anomaly Detection](#). For example, create cost categories for your business units (DevOps Team), and under each category create multiple rules (rules for each sub category) with multiple dimensions (AWS accounts, cost allocation tags, services or charge type) based on your defined groupings. In AWS Cost Explorer and AWS Budgets, a cost category appears as an additional billing dimension. You can use this to filter for the specific cost category value, or group by the cost category.

## Resources

### Related documents:

- [Tagging AWS resources](#)
- [Using Cost Allocation Tags](#)
- [Analyzing your costs with AWS Budgets](#)
- [Analyzing your costs with Cost Explorer](#)
- [Managing AWS Cost and Usage Reports](#)
- [AWS Cost Categories](#)
- [Managing your costs with AWS Cost Categories](#)
- [Creating cost categories](#)
- [Tagging cost categories](#)
- [Splitting charges within cost categories](#)
- [AWS Cost Categories Features](#)

### Related examples:

- [Organize your cost and usage data with AWS Cost Categories](#)
- [Managing your costs with AWS Cost Categories](#)

## COST03-BP04 Establish organization metrics

Establish the organization metrics that are required for this workload. Example metrics of a workload are customer reports produced, or web pages served to customers.

**Level of risk exposed if this best practice is not established:** High

## Implementation guidance

Understand how your workload's output is measured against business success. Each workload typically has a small set of major outputs that indicate performance. If you have a complex workload with many components, then you can prioritize the list, or define and track metrics for each component. Work with your teams to understand which metrics to use. This unit will be used to understand the efficiency of the workload, or the cost for each business output.

### Implementation steps

- **Define workload outcomes:** Meet with the stakeholders in the business and define the outcomes for the workload. These are a primary measure of customer usage and must be business metrics and not technical metrics. There should be a small number of high-level metrics (less than five) per workload. If the workload produces multiple outcomes for different use cases, then group them into a single metric.
- **Define workload component outcomes:** Optionally, if you have a large and complex workload, or can easily break your workload into components (such as microservices) with well-defined inputs and outputs, define metrics for each component. The effort should reflect the value and cost of the component. Start with the largest components and work towards the smaller components.

## Resources

### Related documents:

- [Tagging AWS resources](#)
- [Analyzing your costs with AWS Budgets](#)
- [Analyzing your costs with Cost Explorer](#)
- [Managing AWS Cost and Usage Reports](#)

## COST03-BP05 Configure billing and cost management tools

Configure cost management tools in line with your organization policies to manage and optimize cloud spend. This includes services, tools, and resources to organize and track cost and usage data, enhance control through consolidated billing and access permission, improve planning through budgeting and forecasts, receive notifications or alerts, and further lower cost with resources and pricing optimizations.

**Level of risk exposed if this best practice is not established:** High

## Implementation guidance

To monitor spend and drive the correct usage behaviours, each person in your organization must have access to their cost and usage information. It is recommended that all workloads and teams have the following tools configured when they use the cloud:

- **Organize:** Establish your cost allocation and governance baseline with your own tagging strategy and categorizations.
- **Reports:** Summarize all cost and usage information and raise awareness and accountability of your cloud spend with detailed, allocable cost data.
- **Access:** Track organization-wide billing information in a consolidated view.
- **Control:** Build effective governance mechanisms with the right guardrails.

- **Notifications:** Provide notifications when cost or usage is outside of defined limits.
- **Current State:** Configure a dashboard showing current levels of cost and usage. The dashboard should be available in a highly visible place within the work environment (similar to an operations dashboard).
- **Trending:** Display the variability in cost and usage over the required period of time, with the required granularity.
- **Forecasts:** Show estimated future costs, estimate your resource usage, and spend with forecast dashboards that you create.
- **Tracking:** Show the current cost and usage against configured goals or targets.
- **Analysis:** Allow team members to perform custom and deep analysis down to the hourly granularity, with all possible dimensions.
- **Inspect:** Stay up to date with your resource deployment and cost optimization opportunities.

You can use AWS native tools like [AWS Cost Explorer](#), [AWS Budgets](#), and [Amazon Athena](#) with [Amazon QuickSight](#) to provide this capability or work with [AWS ProServ](#) and use their tools. You can also use third-party tools, but verify first that the cost provides value to your organization.

### Implementation steps

- **Allow team-based access to tools:** Configure your accounts and create groups that have access to the required cost and usage reports for their consumptions and use [AWS Identity and Access Management](#) to [control access](#) to the tools such as AWS Cost Explorer. These groups must include representatives from all teams that own or manage an application. This certifies that every team has access to their cost and usage information to track their consumption.
- **Configure AWS Budgets:** Configure [AWS Budgets](#) on all accounts for your workload. Set budgets for the overall account spend, and budgets for the workloads by using tags. Configure notifications in AWS Budgets to receive alerts for when you exceed your budgeted amounts, or when your estimated costs exceed your budgets.
- **Configure AWS Cost Explorer:** Configure [AWS Cost Explorer](#) for your workload and accounts to visualize your cost data for further analysis. Create a dashboard for the workload that tracks overall spend, key usage metrics for the workload, and forecast of future costs based on your historical cost data.
- **Configure AWS Cost Anomaly Detection:** Use [AWS Cost Anomaly Detection](#) for your accounts, core services, or Cost Categories you created to monitor your cost and usage and detect unusual spends. You can receive alerts individually in aggregated reports, and receive alerts in an email or an Amazon Simple Notification Service topic which allows you to analyze and determine the root cause of the anomaly, and identify the factor that is driving the cost increase.
- **Configure advanced tools:** Optionally, you can create custom tools for your organization that provide additional detail and granularity. You can implement advanced analysis capability using [Amazon Athena](#), and dashboards using [Amazon QuickSight](#). Consider using [Cloud Intelligence Dashboards \(CID\)](#) for pre-configured, advanced dashboards. There are also [AWS Partners](#) you can work with and adopt their cloud management solutions to activate cloud bill monitoring and optimization in one convenient location.

## Resources

### Related documents:

- [AWS Cost Management](#)
- [Tagging AWS resources](#)
- [Analyzing your costs with AWS Budgets](#)
- [Analyzing your costs with Cost Explorer](#)
- [Managing AWS Cost and Usage Reports](#)

- [AWS Cost Categories](#)
- [Cloud Financial Management with AWS](#)
- [AWS APN Partners - Cost Management](#)

**Related videos:**

- [Deploying Cloud Intelligence Dashboards](#)
- [Get Alerts on any FinOps or Cost Optimization Metric or KPI](#)

**Related examples:**

- [Well-Architected Labs - AWS Account Setup](#)
- [Well-Architected Labs: Billing Visualization](#)
- [Well-Architected Labs: Cost and Governance Usage](#)
- [Well-Architected Labs: Cost and Usage Analysis](#)
- [Well-Architected Labs: Cost and Usage Visualization](#)
- [Well-Architected Labs: Cloud Intelligence Dashboards](#)

## COST03-BP06 Allocate costs based on workload metrics

Allocate the workload's costs by metrics or business outcomes to measure workload cost efficiency. Implement a process to analyze the AWS Cost and Usage Report with [Amazon Athena](#), which can provide insight and charge back capability.

**Level of risk exposed if this best practice is not established:** Low

### Implementation guidance

Cost Optimization is delivering business outcomes at the lowest price point, which can only be achieved by allocating workload costs by workload metrics (measured by workload efficiency). Monitor the defined workload metrics through log files or other application monitoring. Combine this data with the workload costs, which can be obtained by looking at costs with a specific tag value or account ID. It is recommended to perform this analysis at the hourly level. Your efficiency will typically change if you have some static cost components (for example, a backend database running 24/7) with a varying request rate (for example, usage peaks at 9am – 5pm, with few requests at night). Understanding the relationship between the static and variable costs will help you to focus your optimization activities.

#### Implementation Steps

- **Allocate costs to workload metrics:** Using the defined metrics and tagging configured, create a metric that combines the workload output and workload cost. Use the analytics services such as Amazon Athena and Amazon QuickSight to create an efficiency dashboard for the overall workload, and any components.

### Resources

**Related documents:**

- [Tagging AWS resources](#)
- [Analyzing your costs with AWS Budgets](#)

- [Analyzing your costs with Cost Explorer](#)
- [Managing AWS Cost and Usage Reports](#)

## Decommission resources

After you manage a list of projects, employees, and technology resources over time you will be able to identify which resources are no longer being used, and which projects that no longer have an owner.

### Best practices

- [COST04-BP01 Track resources over their lifetime \(p. 42\)](#)
- [COST04-BP02 Implement a decommissioning process \(p. 43\)](#)
- [COST04-BP03 Decommission resources \(p. 45\)](#)
- [COST04-BP04 Decommission resources automatically \(p. 46\)](#)
- [COST04-BP05 Enforce data retention policies \(p. 47\)](#)

## COST04-BP01 Track resources over their lifetime

Define and implement a method to track resources and their associations with systems over their lifetime. You can use tagging to identify the workload or function of the resource.

**Level of risk exposed if this best practice is not established:** High

### Implementation guidance

Decommission workload resources that are no longer required. A common example is resources used for testing: after testing has been completed, the resources can be removed. Tracking resources with tags (and running reports on those tags) can help you identify assets for decommission, as they will not be in use or the license on them will expire. Using tags is an effective way to track resources, by labeling the resource with its function, or a known date when it can be decommissioned. Reporting can then be run on these tags. Example values for feature tagging are feature-X testing to identify the purpose of the resource in terms of the workload lifecycle. Another example is using LifeSpan or TTL for the resources, such as to-be-deleted tag key name and value to define the time period or specific time for decommissioning.

### Implementation steps

- **Implement a tagging scheme:** Implement a tagging scheme that identifies the workload the resource belongs to, verifying that all resources within the workload are tagged accordingly. Tagging helps you categorize resources by purpose, team, environment, or other criteria relevant to your business. For more detail on tagging uses cases, strategies, and techniques, see [AWS Tagging Best Practices](#).
- **Implement workload throughput or output monitoring:** Implement workload throughput monitoring or alarming, initiating on either input requests or output completions. Configure it to provide notifications when workload requests or outputs drop to zero, indicating the workload resources are no longer used. Incorporate a time factor if the workload periodically drops to zero under normal conditions. For more detail on unused or underutilized resources, see [AWS Trusted Advisor Cost Optimization checks](#).
- **Group AWS resources:** Create groups for AWS resources. You can use [AWS Resource Groups](#) to organize and manage your AWS resources that are in the same AWS Region. You can add tags to most of your resources to help identify and sort your resources within your organization. Use [Tag Editor](#) add tags to supported resources in bulk. Consider using [AWS Service Catalog](#) to create, manage, and distribute portfolios of approved products to end users and manage the product lifecycle.

## Resources

### Related documents:

- [AWS Auto Scaling](#)
- [AWS Trusted Advisor](#)
- [AWS Trusted Advisor Cost Optimization Checks](#)
- [Tagging AWS resources](#)
- [Publishing Custom Metrics](#)

### Related videos:

- [How to optimize costs using AWS Trusted Advisor](#)

### Related examples:

- [Organize AWS resources](#)
- [Optimize cost using AWS Trusted Advisor](#)

## COST04-BP02 Implement a decommissioning process

Implement a process to identify and decommission unused resources.

**Level of risk exposed if this best practice is not established:** High

## Implementation guidance

Implement a standardized process across your organization to identify and remove unused resources. The process should define the frequency searches are performed and the processes to remove the resource to verify that all organization requirements are met.

### Implementation steps

- **Create and implement a decommissioning process:** Work with the workload developers and owners to build a decommissioning process for the workload and its resources. The process should cover the method to verify if the workload is in use, and also if each of the workload resources are in use. Detail the steps necessary to decommission the resource, removing them from service while ensuring compliance with any regulatory requirements. Any associated resources should be included, such as licenses or attached storage. Notify the workload owners that the decommissioning process has been started.

Use the following decommission steps to guide you on what should be checked as part of your process:

- **Identify resources to be decommissioned:** Identify resources that are eligible for decommissioning in your AWS Cloud. Record all necessary information and schedule the decommission. In your timeline, be sure to account for if (and when) unexpected issues arise during the process.
- **Coordinate and communicate:** Work with workload owners to confirm the resource to be decommissioned
- **Record metadata and create backups:** Record metadata (such as public IPs, Region, AZ, VPC, Subnet, and Security Groups) and create backups (such as Amazon Elastic Block Store snapshots or taking AMI, keys export, and Certificate export) if it is required for the resources in the production environment or if they are critical resources.

- **Validate infrastructure-as-code:** Determine whether resources were deployed with AWS CloudFormation, Terraform, AWS Cloud Development Kit (AWS CDK), or any other infrastructure-as-code deployment tool so they can be re-deployed if necessary.
- **Prevent access:** Apply restrictive controls for a period of time, to prevent the use of resources while you determine if the resource is required. Verify that the resource environment can be reverted to its original state if required.
- **Follow your internal decommissioning process:** Follow the administrative tasks and decommissioning process of your organization, like removing the resource from your organization domain, removing the DNS record, and removing the resource from your configuration management tool, monitoring tool, automation tool and security tools.

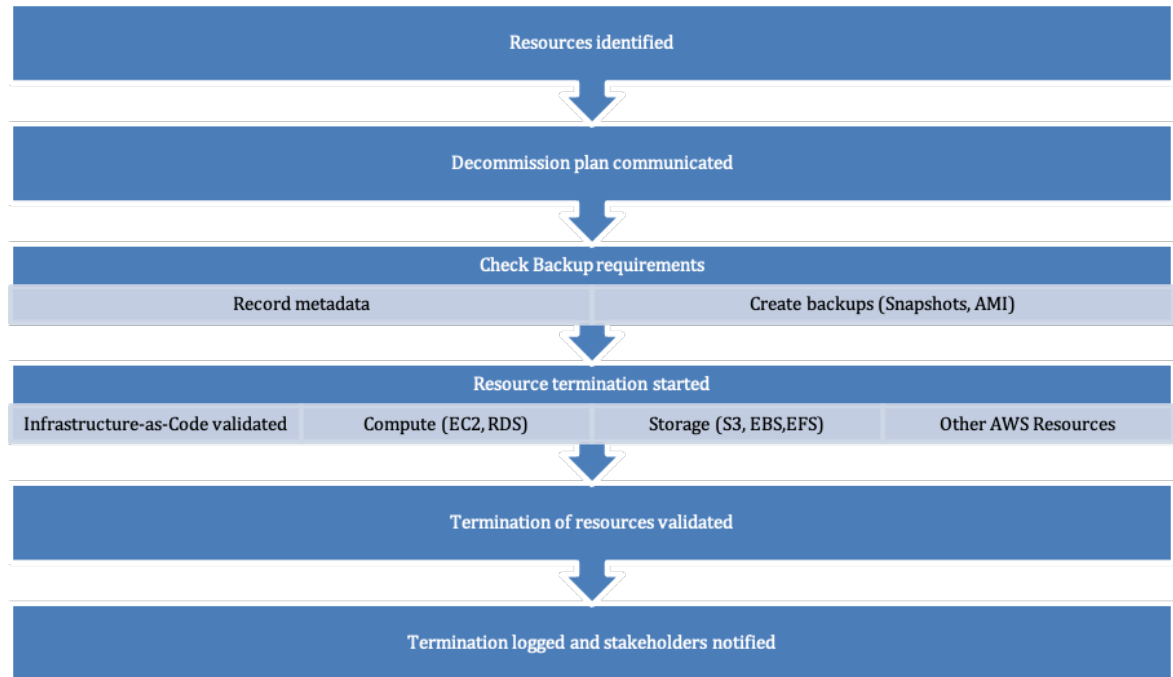
If the resource is an Amazon EC2 instance, consult the following list. [For more detail, see How do I delete or terminate my Amazon EC2 resources?](#)

- Stop or terminate all your Amazon EC2 instances and load balancers. Amazon EC2 instances are visible in the console for a short time after they're terminated. You aren't billed for any instances that aren't in the running state
- Delete your Auto Scaling infrastructure.
- Release all Dedicated Hosts.
- Delete all Amazon EBS volumes and Amazon EBS snapshots.
- Release all Elastic IP addresses.
- Deregister all Amazon Machine Images (AMIs).
- Terminate all AWS Elastic Beanstalk environments.

If the resource is an object in Amazon S3 Glacier storage and if you delete an archive before meeting the minimum storage duration, you will be charged a prorated early deletion fee. Amazon S3 Glacier minimum storage duration depends on the storage class used. For a summary of minimum storage duration for each storage class, see [Performance across the Amazon S3 storage classes](#). For detail on how early deletion fees are calculated, see [Amazon S3 pricing](#).

The following simple decommissioning process flowchart outlines the decommissioning steps. Before decommissioning resources, verify that resources you have identified for decommissioning are not being used by the organization.





*Resource decommissioning flow.*

## Resources

### Related documents:

- [AWS Auto Scaling](#)
- [AWS Trusted Advisor](#)
- [AWS CloudTrail](#)

### Related videos:

- [Delete CloudFormation stack but retain some resources](#)
- [Find out which user launched Amazon EC2 instance](#)

### Related examples:

- [Delete or terminate Amazon EC2 resources](#)
- [Find out which user launched an Amazon EC2 instance](#)

## COST04-BP03 Decommission resources

Decommission resources initiated by events such as periodic audits, or changes in usage. Decommissioning is typically performed periodically and can be manual or automated.

**Level of risk exposed if this best practice is not established:** Medium

## Implementation guidance

The frequency and effort to search for unused resources should reflect the potential savings, so an account with a small cost should be analyzed less frequently than an account with larger costs. Searches and decommission events can be initiated by state changes in the workload, such as a product going end of life or being replaced. Searches and decommission events may also be initiated by external events, such as changes in market conditions or product termination.

### Implementation steps

- **Decommission resources:** This is the depreciation stage of AWS resources that are no longer needed or ending of a licensing agreement. Complete all final checks completed before moving to the disposal stage and decommissioning resources to prevent any unwanted disruptions like taking snapshots or backups. Using the decommissioning process, decommission each of the resources that have been identified as unused.

## Resources

### Related documents:

- [AWS Auto Scaling](#)
- [AWS Trusted Advisor](#)

### Related examples:

- [Well-Architected Labs: Decommission resources \(Level 100\)](#)

## COST04-BP04 Decommission resources automatically

Design your workload to gracefully handle resource termination as you identify and decommission non-critical resources, resources that are not required, or resources with low utilization.

**Level of risk exposed if this best practice is not established:** Low

## Implementation guidance

Use automation to reduce or remove the associated costs of the decommissioning process. Designing your workload to perform automated decommissioning will reduce the overall workload costs during its lifetime. You can use [AWS Auto Scaling](#) to perform the decommissioning process. You can also implement custom code using the [API or SDK](#) to decommission workload resources automatically.

[Modern applications](#) are built serverless-first, a strategy that prioritizes the adoption of serverless services. AWS developed [serverless services](#) for all three layers of your stack: compute, integration, and data stores. Using serverless architecture will allow you to save costs during low-traffic periods with scaling up and down automatically.

### Implementation steps

- **Implement AWS Auto Scaling:** For resources that are supported, configure them with [AWS Auto Scaling](#). AWS Auto Scaling can help you optimize your utilization and cost efficiencies when consuming AWS services. When demand drops, AWS Auto Scaling will automatically remove any excess resource capacity so you avoid overspending.
- **Configure CloudWatch to terminate instances:** Instances can be configured to terminate using [CloudWatch alarms](#). Using the metrics from the decommissioning process, implement an alarm with an

Amazon Elastic Compute Cloud action. Verify the operation in a non-production environment before rolling out.

- **Implement code within the workload:** You can use the AWS SDK or AWS CLI to decommission workload resources. Implement code within the application that integrates with AWS and terminates or removes resources that are no longer used.
- **Use serverless services:** Prioritize building [serverless architectures](#) and [event-driven architecture](#) on AWS to build and run your applications. AWS offers multiple serverless technology services that inherently provide automatically optimized resource utilization and automated decommissioning (scale in and scale out). With serverless applications, resource utilization is automatically optimized and you never pay for over-provisioning.

## Resources

### Related documents:

- [AWS Auto Scaling](#)
- [AWS Trusted Advisor](#)
- [Serverless on AWS](#)
- [Create Alarms to Stop, Terminate, Reboot, or Recover an Instance](#)
- [Getting Started with Amazon EC2 Auto Scaling](#)
- [Adding terminate actions to Amazon CloudWatch alarms](#)

### Related examples:

- [Scheduling automatic deletion of AWS CloudFormation stacks](#)
- [Well-Architected Labs – Decommission resources automatically \(Level 100\)](#)
- [Servian AWS Auto Cleanup](#)

## COST04-BP05 Enforce data retention policies

Define data retention policies on supported resources to handle object deletion per your organizations' requirements. Identify and delete unnecessary or orphaned resources and objects that are no longer required.

**Level of risk exposed if this best practice is not established:** Medium

Use data retention policies and lifecycle policies to reduce the associated costs of the decommissioning process and storage costs for the identified resources. Defining your data retention policies and lifecycle policies to perform automated storage class migration and deletion will reduce the overall storage costs during its lifetime. You can use Amazon Data Lifecycle Manager to automate the creation and deletion of Amazon Elastic Block Store snapshots and Amazon EBS-backed Amazon Machine Images (AMIs), and use Amazon S3 Intelligent-Tiering or an Amazon S3 lifecycle configuration to manage the lifecycle of your Amazon S3 objects. You can also implement custom code using the [API or SDK](#) to create lifecycle policies and policy rules for objects to be deleted automatically.

### Implementation steps

- **Use Amazon Data Lifecycle Manager:** Use lifecycle policies on Amazon Data Lifecycle Manager to automate deletion of Amazon EBS snapshots and Amazon EBS-backed AMIs.
- **Set up lifecycle configuration on a bucket:** Use Amazon S3 lifecycle configuration on a bucket to define actions for Amazon S3 to take during an object's lifecycle, as well as deletion at the end of the object's lifecycle, based on your business requirements.

## Resources

### Related documents:

- [AWS Trusted Advisor](#)
- [Amazon Data Lifecycle Manager](#)
- [How to set lifecycle configuration on Amazon S3 bucket](#)

### Related videos:

- [Automate Amazon EBS Snapshots with Amazon Data Lifecycle Manager](#)
- [Empty an Amazon S3 bucket using a lifecycle configuration rule](#)

### Related examples:

- [Empty an Amazon S3 bucket using a lifecycle configuration rule](#)
- [Well-Architected Lab: Decommission resources automatically \(Level 100\)](#)

# Cost effective resources

Using the appropriate services, resources, and configurations for your workloads is key to cost savings. Consider the following when creating cost-effective resources:

You can use AWS Solutions Architects, AWS Solutions, AWS Reference Architectures, and APN Partners to help you choose an architecture based on what you have learned.

## Topics

- [Evaluate cost when selecting services \(p. 49\)](#)
- [Select the correct resource type, size, and number \(p. 55\)](#)
- [Select the best pricing model \(p. 59\)](#)
- [Plan for data transfer \(p. 69\)](#)

## Evaluate cost when selecting services

### Best practices

- [COST05-BP01 Identify organization requirements for cost \(p. 49\)](#)
- [COST05-BP02 Analyze all components of the workload \(p. 50\)](#)
- [COST05-BP03 Perform a thorough analysis of each component \(p. 51\)](#)
- [COST05-BP04 Select software with cost-effective licensing \(p. 52\)](#)
- [COST05-BP05 Select components of this workload to optimize cost in line with organization priorities \(p. 53\)](#)
- [COST05-BP06 Perform cost analysis for different usage over time \(p. 54\)](#)

## COST05-BP01 Identify organization requirements for cost

Work with team members to define the balance between cost optimization and other pillars, such as performance and reliability, for this workload.

**Level of risk exposed if this best practice is not established:** High

### Implementation guidance

When selecting services for your workload, it is key that you understand your organization priorities. Ensure that you have a balance between cost and other Well-Architected pillars, such as performance and reliability. A fully cost-optimized workload is the solution that is most aligned to your organization's requirements, not necessarily the lowest cost. Meet with all teams within your organization to collect information, such as product, business, technical, and finance.

### Implementation steps

- **Identify organization requirements for cost:** Meet with team members from your organization, including those in product management, application owners, development and operational teams, management, and financial roles. Prioritize the Well-Architected pillars for this workload and its components, the output is a list of the pillars in order. You can also add a weighting to each, which can indicate how much additional focus a pillar has, or how similar the focus is between two pillars.

## Resources

### Related documents:

- [AWS Total Cost of Ownership \(TCO\) Calculator](#)
- [Amazon S3 storage classes](#)
- [Cloud products](#)

## COST05-BP02 Analyze all components of the workload

Verify every workload component is analyzed, regardless of current size or current costs. The review effort should reflect the potential benefit, such as current and projected costs.

**Level of risk exposed if this best practice is not established:** High

## Implementation guidance

Perform a thorough analysis on all components in your workload. Ensure that balance between the cost of analysis and the potential savings in the workload over its lifecycle. You must find the current impact, and potential future impact, of the component. For example, if the cost of the proposed resource is \$10 a month, and under forecasted loads would not exceed \$15 a month, spending a day of effort to reduce costs by 50% (\$5 a month) could exceed the potential benefit over the life of the system. Using a faster and more efficient data-based estimation will create the best overall outcome for this component.

Workloads can change over time, and the right set of services may not be optimal if the workload architecture or usage changes. Analysis for selection of services must incorporate current and future workload states and usage levels. Implementing a service for future workload state or usage may reduce overall costs by reducing or removing the effort required to make future changes.

[AWS Cost Explorer](#) and the [AWS Cost and Usage Report](#) (CUR) can analyze the cost of a Proof of Concept (PoC) or running environment. You can also use [AWS Pricing Calculator](#) to estimate workload costs.

### Implementation steps

- **List the workload components:** Build the list of all the workload components. This is used as verification to check that each component was analyzed. The effort spent should reflect the criticality to the workload as defined by your organization's priorities. Grouping together resources functionally improves efficiency, for example production database storage, if there are multiple databases.
- **Prioritize component list:** Take the component list and prioritize it in order of effort. This is typically in order of the cost of the component from most expensive to least expensive, or the criticality as defined by your organization's priorities.
- **Perform the analysis:** For each component on the list, review the options and services available and chose the option that aligns best with your organizational priorities.

## Resources

### Related documents:

- [AWS Pricing Calculator](#)
- [AWS Cost Explorer](#)
- [Amazon S3 storage classes](#)

- [Cloud products](#)

## COST05-BP03 Perform a thorough analysis of each component

Look at overall cost to the organization of each component. Calculate the total cost of ownership by factoring in cost of operations and management, especially when using managed services by cloud provider. The review effort should reflect potential benefit (for example, time spent analyzing is proportional to component cost).

**Level of risk exposed if this best practice is not established:** High

### Implementation guidance

Consider the time savings that will allow your team to focus on retiring technical debt, innovation, value-adding features and building what differentiates the business. For example, you might need to lift and shift (also known as rehost) your databases from your on-premises environment to the cloud as rapidly as possible and optimize later. It is worth exploring the possible savings attained by using managed services on AWS that may remove or reduce license costs. Managed services on AWS remove the operational and administrative burden of maintaining a service, such as patching or upgrading the OS, and allow you to focus on innovation and business.

Since managed services operate at cloud scale, they can offer a lower cost per transaction or service. You can make potential optimizations in order to achieve some tangible benefit, without changing the core architecture of the application. For example, you may be looking to reduce the amount of time you spend managing database instances by migrating to a database-as-a-service platform like [Amazon Relational Database Service \(Amazon RDS\)](#) or migrating your application to a fully managed platform like [AWS Elastic Beanstalk](#).

Usually, managed services have attributes that you can set to ensure sufficient capacity. You must set and monitor these attributes so that your excess capacity is kept to a minimum and performance is maximized. You can modify the attributes of AWS Managed Services using the AWS Management Console or AWS APIs and SDKs to align resource needs with changing demand. For example, you can increase or decrease the number of nodes on an Amazon EMR cluster (or an Amazon Redshift cluster) to scale out or in.

You can also pack multiple instances on an AWS resource to activate higher density usage. For example, you can provision multiple small databases on a single Amazon Relational Database Service (Amazon RDS) database instance. As usage grows, you can migrate one of the databases to a dedicated Amazon RDS database instance using a snapshot and restore process.

When provisioning workloads on managed services, you must understand the requirements of adjusting the service capacity. These requirements are typically time, effort, and any impact to normal workload operation. The provisioned resource must allow time for any changes to occur, provision the required overhead to allow this. The ongoing effort required to modify services can be reduced to virtually zero by using APIs and SDKs that are integrated with system and monitoring tools, such as Amazon CloudWatch.

[Amazon RDS](#), [Amazon Redshift](#), and [Amazon ElastiCache](#) provide a managed database service. [Amazon Athena](#), [Amazon EMR](#), and [Amazon OpenSearch Service](#) provide a managed analytics service.

[AMS](#) is a service that operates AWS infrastructure on behalf of enterprise customers and partners. It provides a secure and compliant environment that you can deploy your workloads onto. AMS uses enterprise cloud operating models with automation to allow you to meet your organization requirements, move into the cloud faster, and reduce your on-going management costs.

### Implementation steps

- **Perform a thorough analysis:** Using the component list, work through each component from the highest priority to the lowest priority. For the higher priority and more costly components, perform additional analysis and assess all available options and their long term impact. For lower priority components, assess if changes in usage would change the priority of the component, and then perform an analysis of appropriate effort.
- **Compare managed and unmanaged resources:** Consider the operational cost for the resources you manage and compare them with AWS managed resources. For example, review your databases running on Amazon EC2 instances and compare with Amazon RDS options (an AWS managed service) or Amazon EMR compared to running Apache Spark on Amazon EC2. When moving from a self-managed workload to a AWS fully managed workload, research your options carefully. The three most important factors to consider are the [type of managed service](#) you want to use, the process you will use to [migrate your data](#) and understand the [AWS shared responsibility model](#).

## Resources

### Related documents:

- [AWS Total Cost of Ownership \(TCO\) Calculator](#)
- [Amazon S3 storage classes](#)
- [AWS Cloud products](#)
- [AWS Shared Responsibility Model](#)

### Related videos:

- [Why move to a managed database?](#)
- [What is Amazon EMR and how can I use it for processing data?](#)

### Related examples:

- [Why to move to a managed database](#)
- [Consolidate data from identical SQL Server databases into a single Amazon RDS for SQL Server database using AWS DMS](#)
- [Deliver data at scale to Amazon Managed Streaming for Apache Kafka \(Amazon MSK\)](#)
- [Migrate an ASP.NET web application to AWS Elastic Beanstalk](#)

## COST05-BP04 Select software with cost-effective licensing

Open-source software eliminates software licensing costs, which can contribute significant costs to workloads. Where licensed software is required, avoid licenses bound to arbitrary attributes such as CPUs, look for licenses that are bound to output or outcomes. The cost of these licenses scales more closely to the benefit they provide.

**Level of risk exposed if this best practice is not established:** Low

## Implementation guidance

The cost of software licenses can be eliminated through the use of open-source software. This can have significant impact on workload costs as the size of the workload scales. Measure the benefits of licensed software against the total cost to ensure that you have the most optimized workload. Model any changes in licensing and how they would impact your workload costs. If a vendor changes the



cost of your database license, investigate how that impacts the overall efficiency of your workload. Consider historical pricing announcements from your vendors for trends of licensing changes across their products. Licensing costs may also scale independently of throughput or usage, such as licenses that scale by hardware (CPU-bound licenses). These licenses should be avoided because costs can rapidly increase without corresponding outcomes.

#### Implementation steps

- **Analyze license options:** Review the licensing terms of available software. Look for open-source versions that have the required functionality, and whether the benefits of licensed software outweigh the cost. Favorable terms will align the cost of the software to the benefit it provides.
- **Analyze the software provider:** Review any historical pricing or licensing changes from the vendor. Look for any changes that do not align to outcomes, such as punitive terms for running on specific vendors hardware or platforms. Additionally look for how they run audits, and penalties that could be imposed.

## Resources

#### Related documents:

- [AWS Total Cost of Ownership \(TCO\) Calculator](#)
- [Amazon S3 storage classes](#)
- [Cloud products](#)

## COST05-BP05 Select components of this workload to optimize cost in line with organization priorities

Factor in cost when selecting all components for your workload. This includes using application level and managed services or serverless, containers, or event-driven architecture to reduce overall cost. Minimize license costs by using open-source software, software that does not have license fees, or alternatives to reduce the cost.

**Level of risk exposed if this best practice is not established:** Medium

## Implementation guidance

Consider the cost of services and options when selecting all components. This includes using application level and managed services, such as [Amazon Relational Database Service \(Amazon RDS\)](#), [Amazon DynamoDB](#), [Amazon Simple Notification Service \(Amazon SNS\)](#), and [Amazon Simple Email Service \(Amazon SES\)](#) to reduce overall organization cost. Use serverless and containers for compute, such as [AWS Lambda](#) and [Amazon Simple Storage Service \(Amazon S3\)](#) for static websites. Containerize your application if possible and use AWS Managed Container Services such as [Amazon Elastic Container Service \(Amazon ECS\)](#) or [Amazon Elastic Kubernetes Service \(Amazon EKS\)](#). Minimize license costs by using open-source software, or software that does not have license fees (for example, Amazon Linux for compute workloads or migrate databases to Amazon Aurora).

You can use serverless or application-level services such as [AWS Lambda](#), [Amazon Simple Queue Service \(Amazon SQS\)](#), [Amazon SNS](#), and [Amazon SES](#). These services remove the need for you to manage a resource, and provide the function of running code, queuing services, and message delivery. The other benefit is that they scale in performance and cost in line with usage, allowing efficient cost allocation and attribution.

Using [event-driven architecture \(EDA\)](#) is also possible with serverless services. Event-driven architectures are push-based, so everything happens on demand as the event presents itself in the router. This way,

you're not paying for continuous polling to check for an event. This means less network bandwidth consumption, less CPU utilization, less idle fleet capacity, and fewer SSL/TLS handshakes.

For more information on Serverless, refer to the [Well-Architected Serverless Application Lens whitepaper](#).

### Implementation steps

- **Select each service to optimize cost:** Using your prioritized list and analysis, select each option that provides the best match with your organizational priorities. Instead of increasing the capacity to meet the demand, consider other options which may give you better performance with lower cost. For example, you need to review expected traffic for your databases on AWS and consider either increasing the instance size or using Amazon ElastiCache services (Redis or Memcached) to provide cached mechanisms for your databases.
- **Evaluate event-driven architecture:** Using serverless architecture also allows you to build event-driven architecture for distributed microservice-based applications, which helps you build scalable, resilient, agile and cost-effective solutions.

## Resources

### Related documents:

- [AWS Total Cost of Ownership \(TCO\) Calculator](#)
- [AWS Serverless](#)
- [What is Event-Driven Architecture](#)
- [Amazon S3 storage classes](#)
- [Cloud products](#)
- [Amazon ElastiCache for Redis](#)

### Related examples:

- [Getting started with event-driven architecture](#)
- [What is an Event-Driven Architecture?](#)
- [How Statsig runs 100x more cost-effectively using Amazon ElastiCache for Redis](#)
- [Best practices for working with AWS Lambda functions](#)

## COST05-BP06 Perform cost analysis for different usage over time

Workloads can change over time. Some services or features are more cost effective at different usage levels. By performing the analysis on each component over time and at projected usage, the workload remains cost-effective over its lifetime.

**Level of risk exposed if this best practice is not established:** Medium

## Implementation guidance

As AWS releases new services and features, the optimal services for your workload may change. Effort required should reflect potential benefits. Workload review frequency depends on your organization requirements. If it is a workload of significant cost, implementing new services sooner will maximize cost savings, so more frequent review can be advantageous. Another initiation for review is change in usage patterns. Significant changes in usage can indicate that alternate services would be more optimal.

If you need to move data into AWS Cloud, you can select any wide variety of services AWS offers and partner tools to help you migrate your data sets, whether they are files, databases, machine images, block volumes, or even tape backups. For example, to move a large amount of data to and from AWS or process data at the edge, you can use one of the AWS purpose-built devices to cost effectively move petabytes of data offline. Another example is for higher data transfer rates, a direct connect service may be cheaper than a VPN which provides the required consistent connectivity for your business.

Based on the cost analysis for different usage over time, review your scaling activity. Analyze the result to see if the scaling policy can be tuned to add instances with multiple instance types and purchase options. Review your settings to see if the minimum can be reduced to serve user requests but with a smaller fleet size, and add more resources to meet the expected high demand.

Perform cost analysis for different usage over time by discussing with stakeholders in your organization and use [AWS Cost Explorer's](#) forecast feature to predict the potential impact of service changes. Monitor usage level launches using AWS Budgets, CloudWatch billing alarms and AWS Cost Anomaly Detection to identify and implement the most cost-effective services sooner.

### Implementation steps

- **Define predicted usage patterns:** Working with your organization, such as marketing and product owners, document what the expected and predicted usage patterns will be for the workload. Discuss with business stakeholders about both historical and forecasted cost and usage increases and make sure increases align with business requirements. Identify calendar days, weeks, or months where you expect more users to use your AWS resources, which indicate that you should increase the capacity of the existing resources or adopt additional services to reduce the cost and increase performance.
- **Perform cost analysis at predicted usage:** Using the usage patterns defined, perform analysis at each of these points. The analysis effort should reflect the potential outcome. For example, if the change in usage is large, a thorough analysis should be performed to verify any costs and changes. In other words, when cost increases, usage should increase for business as well.

## Resources

### Related documents:

- [AWS Total Cost of Ownership \(TCO\) Calculator](#)
- [Amazon S3 storage classes](#)
- [Cloud products](#)
- [Amazon EC2 Auto Scaling](#)
- [Cloud Data Migration](#)
- [AWS Snow Family](#)

### Related videos:

- [AWS OpsHub for Snow Family](#)

## Select the correct resource type, size, and number

By selecting the best resource type, size, and number of resources, you meet the technical requirements with the lowest cost resource. Right-sizing activities takes into account all of the resources of a workload, all of the attributes of each individual resource, and the effort involved in the right-sizing operation. Right-sizing can be an iterative process, initiated by changes in usage patterns and external factors, such as AWS price drops or new AWS resource types. Right-sizing can also be one-off if the cost of the effort to right-size, outweighs the potential savings over the life of the workload.

In AWS, there are a number of different approaches:

#### Best practices

- [COST06-BP01 Perform cost modeling \(p. 56\)](#)
- [COST06-BP02 Select resource type, size, and number based on data \(p. 57\)](#)
- [COST06-BP03 Select resource type, size, and number automatically based on metrics \(p. 58\)](#)

## COST06-BP01 Perform cost modeling

Identify organization requirements (such as business needs and existing commitments) and perform cost modeling (overall costs) of the workload and each of its components. Perform benchmark activities for the workload under different predicted loads and compare the costs. The modeling effort should reflect the potential benefit. For example, time spent is proportional to component cost.

**Level of risk exposed if this best practice is not established:** High

### Implementation guidance

Perform cost modelling for your workload and each of its components to understand the balance between resources, and find the correct size for each resource in the workload, given a specific level of performance. Understanding cost considerations can inform your organizational business case and decision-making process when evaluating the value realization outcomes for planned workload deployment.

Perform benchmark activities for the workload under different predicted loads and compare the costs. The modelling effort should reflect potential benefit; for example, time spent is proportional to component cost or predicted saving. For best practices, refer to the [Review section of the Performance Efficiency Pillar of the AWS Well-Architected Framework](#).

As an example, to create cost modeling for a workload consisting of compute resources, [AWS Compute Optimizer](#) can assist with cost modelling for running workloads. It provides right-sizing recommendations for compute resources based on historical usage. Make sure CloudWatch Agents are deployed to the Amazon EC2 instances to collect memory metrics which help you with more accurate recommendations within AWS Compute Optimizer. This is the ideal data source for compute resources because it is a free service that uses machine learning to make multiple recommendations depending on levels of risk.

There are [multiple services](#) you can use with custom logs as data sources for rightsizing operations for other services and workload components, such as [AWS Trusted Advisor](#), [Amazon CloudWatch](#) and [Amazon CloudWatch Logs](#). AWS Trusted Advisor checks resources and flags resources with low utilization which can help you right size your resources and create cost modelling.

The following are recommendations for cost modelling data and metrics:

- The monitoring must accurately reflect the user experience. Select the correct granularity for the time period and thoughtfully choose the maximum or 99th percentile instead of the average.
- Select the correct granularity for the time period of analysis that is required to cover any workload cycles. For example, if a two-week analysis is performed, you might be overlooking a monthly cycle of high utilization, which could lead to under-provisioning.
- Choose the right AWS services for your planned workload by considering your existing commitments, selected pricing models for other workloads, and ability to innovate faster and focus on your core business value.

#### Implementation steps

- **Perform cost modeling for resources:** Deploy the workload or a proof of concept into a separate account with the specific resource types and sizes to test. Run the workload with the test data and record the output results, along with the cost data for the time the test was run. Afterwards, redeploy the workload or change the resource types and sizes and run the test again. Include license fees of any products you may use with these resources and estimated operations (labor or engineer) costs for deploying and managing these resources while creating cost modeling. Consider cost modeling for a period (hourly, daily, monthly, yearly or three years).

## Resources

### Related documents:

- [AWS Auto Scaling](#)
- [Identifying Opportunities to Right Size](#)
- [Amazon CloudWatch features](#)
- [Cost Optimization: Amazon EC2 Right Sizing](#)
- [AWS Compute Optimizer](#)
- [AWS Pricing Calculator](#)

### Related examples:

- [Perform a Data-Driven Cost Modelling](#)
- [Estimate the cost of planned AWS resource configurations](#)
- [Choose the right AWS tools](#)

## COST06-BP02 Select resource type, size, and number based on data

Select resource size or type based on data about the workload and resource characteristics. For example, compute, memory, throughput, or write intensive. This selection is typically made using a previous (on-premises) version of the workload, using documentation, or using other sources of information about the workload.

**Level of risk exposed if this best practice is not established:** Medium

## Implementation guidance

Select resource size or type based on workload and resource characteristics, for example, compute, memory, throughput, or write intensive. This selection is typically made using cost modelling, a previous version of the workload (such as an on-premises version), using documentation, or using other sources of information about the workload (whitepapers, published solutions).

### Implementation steps

- **Select resources based on data:** Using your cost modeling data, select the expected workload usage level, then select the specified resource type and size.

## Resources

### Related documents:

- [AWS Auto Scaling](#)
- [Amazon CloudWatch features](#)
- [Cost Optimization: EC2 Right Sizing](#)

## COST06-BP03 Select resource type, size, and number automatically based on metrics

Use metrics from the currently running workload to select the right size and type to optimize for cost. Appropriately provision throughput, sizing, and storage for compute, storage, data, and networking services. This can be done with a feedback loop such as automatic scaling or by custom code in the workload.

**Level of risk exposed if this best practice is not established:** Low

### Implementation guidance

Create a feedback loop within the workload that uses active metrics from the running workload to make changes to that workload. You can use a managed service, such as [AWS Auto Scaling](#), which you configure to perform the right sizing operations for you. AWS also provides [APIs](#), [SDKs](#), and features that allow resources to be modified with minimal effort. You can program a workload to stop-and-start an Amazon EC2 instance to allow a change of instance size or instance type. This provides the benefits of right-sizing while removing almost all the operational cost required to make the change.

Some AWS services have built in automatic type or size selection, such as [Amazon Simple Storage Service Intelligent-Tiering](#). Amazon S3 Intelligent-Tiering automatically moves your data between two access tiers, frequent access and infrequent access, based on your usage patterns.

### Implementation steps

- **Increase your observability by configuring workload metrics:** Capture key metrics for the workload. These metrics provide an indication of the customer experience, such as workload output, and align to the differences between resource types and sizes, such as CPU and memory usage. For compute resource, analyze performance data to right size your Amazon EC2 instances. Identify idle instances and ones that are underutilized. Key metrics to look for are CPU usage and memory utilization (for example, 40% CPU utilization at 90% of the time as explained in [Rightsizing with AWS Compute Optimizer and Memory Utilization Enabled](#)). Identify instances with a maximum CPU usage and memory utilization of less than 40% over a four-week period. These are the instances to right size to reduce costs. For storage resources such as Amazon S3, you can use [Amazon S3 Storage Lens](#), which allows you to see 28 metrics across various categories at the bucket level, and 14 days of historical data in the dashboard by default. You can filter your Amazon S3 Storage Lens dashboard by summary and cost optimization or events to analyze specific metrics.
- **View rightsizing recommendations:** Use the rightsizing recommendations in AWS Compute Optimizer and the Amazon EC2 rightsizing tool in the Cost Management console, or review AWS Trusted Advisor right-sizing your resources to make adjustments on your workload. It is important to use the [right tools](#) when right-sizing different resources and follow [right-sizing guidelines](#) whether it is an Amazon EC2 instance, AWS storage classes, or Amazon RDS instance types. For storage resources, you can use Amazon S3 Storage Lens, which gives you visibility into object storage usage, activity trends, and makes actionable recommendations to optimize costs and apply data protection best practices. Using the contextual recommendations that [Amazon S3 Storage Lens](#) derives from analysis of metrics across your organization, you can take immediate steps to optimize your storage.
- **Select resource type and size automatically based on metrics:** Using the workload metrics, manually or automatically select your workload resources. For compute resources, configuring AWS Auto Scaling or implementing code within your application can reduce the effort required if frequent changes are needed, and it can potentially implement changes sooner than a manual process. You can launch and

automatically scale a fleet of On-Demand Instances and Spot Instances within a single Auto Scaling group. In addition to receiving discounts for using Spot Instances, you can use Reserved Instances or a Savings Plan to receive discounted rates of the regular On-Demand Instance pricing. All of these factors combined help you optimize your cost savings for Amazon EC2 instances and determine the desired scale and performance for your application. You can also use an [attribute-based instance type selection \(ABS\)](#) strategy in [Auto Scaling Groups \(ASG\)](#), which lets you express your instance requirements as a set of attributes, such as vCPU, memory, and storage. You can automatically use newer generation instance types when they are released and access a broader range of capacity with Amazon EC2 Spot Instances. Amazon EC2 Fleet and Amazon EC2 Auto Scaling select and launch instances that fit the specified attributes, removing the need to manually pick instance types. For storage resources, you can use the [Amazon S3 Intelligent Tiering](#) and [Amazon EFS Infrequent Access](#) features, which allow you to select storage classes automatically that deliver automatic storage cost savings when data access patterns change, without performance impact or operational overhead.

## Resources

### Related documents:

- [AWS Auto Scaling](#)
- [AWS Right-Sizing](#)
- [AWS Compute Optimizer](#)
- [Amazon CloudWatch features](#)
- [CloudWatch Getting Set Up](#)
- [CloudWatch Publishing Custom Metrics](#)
- [Getting Started with Amazon EC2 Auto Scaling](#)
- [Amazon S3 Storage Lens](#)
- [Amazon S3 Intelligent-Tiering](#)
- [Amazon EFS Infrequent Access](#)
- [Launch an Amazon EC2 Instance Using the SDK](#)

### Related videos:

- [Right Size Your Services](#)

### Related examples:

- [Attribute based Instance Type Selection for Auto Scaling for Amazon EC2 Fleet](#)
- [Optimizing Amazon Elastic Container Service for cost using scheduled scaling](#)
- [Predictive scaling with Amazon EC2 Auto Scaling](#)
- [Optimize Costs and Gain Visibility into Usage with Amazon S3 Storage Lens](#)
- [Well-Architected Labs: Rightsizing Recommendations \(Level 100\)](#)
- [Well-Architected Labs: Rightsizing with AWS Compute Optimizer and Memory Utilization Enabled \(Level 200\)](#)

## Select the best pricing model

**Perform workload cost modeling:** Consider the requirements of the workload components and understand the potential pricing models. Define the availability requirement of the component.



Determine if there are multiple independent resources that perform the function in the workload, and what the workload requirements are over time. Compare the cost of the resources using the default On-Demand pricing model and other applicable models. Factor in any potential changes in resources or workload components.

**Perform regular account level analysis:** Performing regular cost modeling ensures that opportunities to optimize across multiple workloads can be implemented. For example, if multiple workloads use On-Demand, at an aggregate level, the risk of change is lower, and implementing a commitment-based discount will achieve a lower overall cost. It is recommended to perform analysis in regular cycles of two weeks to one month. This analysis allows you to make small adjustment purchases, so the coverage of your pricing models continues to evolve with your changing workloads and their components.

Use the [AWS Cost Explorer](#) recommendations tool to find opportunities for commitment discounts.

To find opportunities for Spot workloads, use an hourly view of your overall usage, and look for regular periods of changing usage or elasticity.

**Pricing models:** AWS has multiple [pricing models](#) that allow you to pay for your resources in the most cost-effective way that suits your organization's needs. The following section describes each purchasing model:

- On-Demand Instances
- Spot Instances
- Commitment discounts - Savings Plans
- Commitment discounts - Reserved Instances/Capacity
- Geographic selection
- Third-party agreements and pricing

**On-Demand Instances:** This is the default, pay as you go pricing model. When you use resources (for example, EC2 instances or services such as DynamoDB on demand) you pay a flat rate, and you have no long-term commitments. You can increase or decrease the capacity of your resources or services based on the demands of your application. On-Demand has an hourly rate, but depending on the service, can be billed in increments of one second (for example Amazon RDS, or Linux EC2 instances). On demand is recommended for applications with short-term workloads (for example, a four-month project), that spike periodically, or unpredictable workloads that can't be interrupted. On demand is also suitable for workloads, such as pre-production environments, which require uninterrupted runtimes, but do not run long enough for a commitment discount (Savings Plans or Reserved Instances).

**Spot Instances:** A [Spot Instance](#) is spare Amazon EC2 compute capacity available at discounts of up to 90% off On-Demand prices with no long-term commitment required. With Spot Instances, you can significantly reduce the cost of running your applications or scale your application's compute capacity for the same budget. Unlike On-Demand, Spot Instances can be interrupted with a 2-minute warning if Amazon EC2 needs the capacity back, or the Spot Instance price exceeds your configured price. On average, Spot Instances are interrupted less than 5% of the time.

Spot Instances are ideal when there is a queue or buffer in place, or where there are multiple resources working independently to process the requests (for example, Hadoop data processing). Typically these workloads are fault-tolerant, stateless, and flexible, such as batch processing, big data and analytics, containerized environments, and high performance computing (HPC). Non-critical workloads such as test and development environments are also candidates for Spot.

Spot Instances are also integrated into multiple AWS services, such as Amazon EC2 Auto Scaling groups, Amazon EMR, Amazon Elastic Container Service (Amazon ECS), and AWS Batch.

When a Spot Instance needs to be reclaimed, Amazon EC2 sends a two-minute warning via a Spot Instance interruption notice delivered through CloudWatch Events, as well as in the instance metadata.



During that two-minute period, your application can use the time to save its state, drain running containers, upload final log files, or remove itself from a load balancer. At the end of the two minutes, you have the option to hibernate, stop, or terminate the Spot Instance.

Consider the following best practices when adopting Spot Instances in your workloads:

- **Be flexible across as many instance types as possible:** Be flexible in both the family and size of the instance type, to improve the likelihood of fulfilling your target capacity requirements, obtain the lowest possible cost, and minimize the impact of interruptions.
- **Be flexible about where your workload will run:** Available capacity can vary by Availability Zone. This improves the likelihood of fulfilling your target capacity by tapping into multiple spare capacity pools, and provides the lowest possible cost.
- **Design for continuity:** Design your workloads for statelessness and fault-tolerance, so that if some of your EC2 capacity gets interrupted, it will not have impact on the availability or performance of the workload.
- We recommend using Spot Instances in combination with On-Demand and Savings Plans/Reserved Instances to maximize workload cost optimization with performance.

**Commitment discounts – Savings Plans:** AWS provides a number of ways for you to reduce your costs by reserving or committing to use a certain amount of resources, and receiving a discounted rate for your resources. A [Savings Plan](#) allows you to make an hourly spend commitment for one or three years, and receive discounted pricing across your resources. Savings Plans provide discounts for AWS Compute services such as Amazon EC2, AWS Fargate, and AWS Lambda. When you make the commitment, you pay that commitment amount every hour, and it is subtracted from your On-Demand usage at the discount rate. For example, you commit to \$50 an hour, and have \$150 an hour of On-Demand usage. Considering the Savings Plans pricing, your specific usage has a discount rate of 50%. So, your \$50 commitment covers \$100 of On-Demand usage. You will pay \$50 (commitment) and \$50 of remaining On-Demand usage.

[Compute Savings Plans](#) are the most flexible and provide a discount of up to 66%. They automatically apply across Availability Zones, instance size, instance family, operating system, tenancy, Region, and compute service.

[Instance Savings Plans](#) have less flexibility but provide a higher discount rate (up to 72%). They automatically apply across Availability Zones, instance size, instance family, operating system, and tenancy.

There are three payment options:

- **No upfront payment:** There is no upfront payment; you then pay a reduced hourly rate each month for the total hours in the month.
- **Partial upfront payment:** Provides a higher discount rate than No upfront. Part of the usage is paid up front; you then pay a smaller reduced hourly rate each month for the total hours in the month.
- **All upfront payment:** Usage for the entire period is paid up front, and no other costs are incurred for the remainder of the term for usage that is covered by the commitment.

You can apply any combination of these three purchasing options across your workloads.

Savings plans apply first to the usage in the account they are purchased in, from the highest discount percentage to the lowest, then they apply to the consolidated usage across all other accounts, from the highest discount percentage to the lowest.

It is recommended to purchase all Savings Plans in an account with no usage or resources, such as the management account. This ensures that the Savings Plan applies to the highest discount rates across all of your usage, maximizing the discount amount.

Workloads and usage typically change over time. It is recommended to continually purchase small amounts of Savings Plans commitment over time. This ensures that you maintain high levels of coverage to maximize your discounts, and your plans closely match your workload and organization requirements at all times.

Do not set a target coverage in your accounts, due to the variability of discount that is possible. Low coverage does not necessarily indicate high potential savings. You may have a low coverage in your account, but if your usage is made up of small instances, with a licensed operating system, the potential saving could be as low as a few percent. Instead, track and monitor the potential savings available in the Savings Plan recommendation tool. Frequently review the Savings Plans recommendations in Cost Explorer (perform regular analysis) and continue to purchase commitments until the estimated savings are below the required discount for the organization. For example, track and monitor that your potential discounts remained below 20%, if it goes above that a purchase must be made.

Monitor the utilization and coverage, but only to detect changes. Do not aim for a specific utilization percent, or coverage percent, as this does not necessarily scale with savings. Ensure that a purchase of Savings Plans results in an increase in coverage, and if there are decreases in coverage or utilization ensure they are quantified and known. For example, you migrate a workload resource to a newer instance type, which reduces utilization of an existing plan, but the performance benefit outweighs the saving reduction.

**Commitment discounts – Reserved Instances/Commitment:** Similar to Savings Plans, [Reserved Instances](#) (RI) offer discounts up to 72% for a commitment to running a minimum amount of resources. Reserved Instances are available for Amazon RDS, Amazon OpenSearch Service, Amazon ElastiCache, Amazon Redshift, and DynamoDB. Amazon CloudFront and AWS Elemental MediaConvert also provide discounts when you make minimum usage commitments. Reserved Instances are currently available for Amazon EC2, however Savings Plans offer the same discount levels with increased flexibility and no management overhead.

Reserved Instances offer the same pricing options of no upfront, partial upfront, and all upfront, and the same terms of one or three years.

Reserved Instances can be purchased in a Region or a specific Availability Zone. They provide a capacity reservation when purchased in an Availability Zone.

Amazon EC2 features convertible RIs, however, Savings Plans should be used for all EC2 instances due to increased flexibility and reduced operational costs.

The same process and metrics should be used to track and make purchases of Reserved Instances. It is recommended to not track coverage of RIs across your accounts. It is also recommended that utilization percentage is not monitored or tracked, instead view the utilization report in Cost Explorer, and use net savings column in the table. If the net savings is a significantly large negative amount, you must take action to remediate the unused RI.

**EC2 Fleet:** [EC2 Fleet](#) is a feature that allows you to define a target compute capacity, and then specify the instance types and the balance of On-Demand and Spot Instances for the fleet. EC2 Fleet will automatically launch the lowest price combination of resources to meet the defined capacity.

**Geographic selection:** When you architect your solutions, a best practice is to seek to place computing resources closer to users to provide lower latency and strong data sovereignty. For global audiences, you should use multiple locations to meet these needs. You should select the geographic location that minimizes your costs.

The AWS Cloud infrastructure is built around [Regions and Availability Zones](#). A Region is a physical location in the world where we have multiple Availability Zones. Availability Zones consist of one or more discrete data centers, each with redundant power, networking, and connectivity, housed in separate facilities.

Each AWS Region operates within local market conditions, and resource pricing is different in each Region. Choose a specific Region to operate a component of or your entire solution so that you can run

at the lowest possible price globally. You can use the AWS Simple Monthly Calculator to estimate the costs of your workload in various Regions.

**Third-party agreements and pricing:** When you use third-party solutions or services in the cloud, it is important that the pricing structures are aligned to Cost Optimization outcomes. Pricing should scale with the outcomes and value it provides. An example of this is software that takes a percentage of savings it provides, the more you save (outcome) the more it charges. Agreements that scale with your bill are typically not aligned to Cost Optimization, unless they provide outcomes for every part of your specific bill. For example, a solution that provides recommendations for Amazon EC2 and charges a percentage of your entire bill will increase if you use other services for which it provides no benefit. Another example is a managed service that is charged at a percentage of the cost of resources that are managed. A larger instance size may not necessarily require more management effort, but will be charged more. Ensure that these service pricing arrangements include a cost optimization program or features in their service to drive efficiency.

#### Best practices

- [COST07-BP01 Perform pricing model analysis \(p. 63\)](#)
- [COST07-BP02 Implement Regions based on cost \(p. 65\)](#)
- [COST07-BP03 Select third-party agreements with cost-efficient terms \(p. 66\)](#)
- [COST07-BP04 Implement pricing models for all components of this workload \(p. 67\)](#)
- [COST07-BP05 Perform pricing model analysis at the management account level \(p. 68\)](#)

## COST07-BP01 Perform pricing model analysis

Analyze each component of the workload. Determine if the component and resources will be running for extended periods (for commitment discounts) or dynamic and short-running (for spot or on-demand). Perform an analysis on the workload using the recommendations in cost management tools and apply business rules to those recommendations to achieve high returns.

**Level of risk exposed if this best practice is not established:** High

### Implementation guidance

AWS has multiple [pricing models](#) that allow you to pay for your resources in the most cost-effective way that suits your organization's needs and depending on product. Work with your teams to determine the most appropriate pricing model. Often your pricing model consists of a combination of multiple options, as determined by your availability

**On-Demand Instances** allow you pay for compute or database capacity by the hour or by the second (60 seconds minimum) depending on which instances you run, without long-term commitments or upfront payments.

**Savings Plans** are a flexible pricing model that offers low prices on Amazon EC2, Lambda, and AWS Fargate (Fargate) usage, in exchange for a commitment to a consistent amount of usage (measured in dollars per hour) over one year or three years terms.

**Spot Instances** are an Amazon EC2 pricing mechanism that allows you request spare compute capacity at discounted hourly rate (up to 90% off the on-demand price) without upfront commitment.

**Reserved Instances** allow you up to 75 percent discount by prepaying for capacity. For more details, see [Optimizing costs with reservations](#).

You might choose to include a Savings Plan for the resources associated with the production, quality, and development environments. Alternatively, because sandbox resources are only powered on when needed, you might choose an on-demand model for the resources in that environment. Use Amazon

[Spot Instances](#) to reduce Amazon EC2 costs or use [Compute Savings Plans](#) to reduce Amazon EC2, Fargate, and Lambda cost. The [AWS Cost Explorer](#) recommendations tool provides opportunities for commitment discounts with Saving plans.

If you have been purchasing [Reserved Instances](#) for Amazon EC2 in the past or have established cost allocation practices inside your organization, you can continue using Amazon EC2 Reserved Instances for the time being. However, we recommend working on a strategy to use Savings Plans in the future as a more flexible cost savings mechanism. You can refresh Savings Plans (SP) Recommendations in AWS Cost Management to generate new Savings Plans Recommendations at any time. Use Reserved Instances (RI) to reduce Amazon RDS, Amazon Redshift, Amazon ElastiCache, and Amazon OpenSearch Service costs. Saving Plans and Reserved Instances are available in three options: all upfront, partial upfront and no upfront payments. Use the recommendations provided in AWS Cost Explorer RI and SP purchase recommendations.

To find opportunities for Spot workloads, use an hourly view of your overall usage, and look for regular periods of changing usage or elasticity. You can use Spot Instances for various fault-tolerant and flexible applications. Examples include stateless web servers, API endpoints, big data and analytics applications, containerized workloads, CI/CD, and other flexible workloads.

Analyze your Amazon EC2 and Amazon RDS instances whether they can be turned off when you don't use (after hours and weekends). This approach will allow you to reduce costs by 70% or more compared to using them 24/7. If you have Amazon Redshift clusters that only need to be available at specific times, you can pause the cluster and later resume it. When the Amazon Redshift cluster or Amazon EC2 and Amazon RDS Instance is stopped, the compute billing halts and only the storage charge applies.

Note that [On-Demand Capacity reservations](#) (ODCR) are not a pricing discount. Capacity Reservations are charged at the equivalent On-Demand rate, whether you run instances in reserved capacity or not. They should be considered when you need to provide enough capacity for the resources you plan to run. ODCRs don't have to be tied to long-term commitments, as they can be cancelled when you no longer need them, but they can also benefit from the discounts that Savings Plans or Reserved Instances provide.

### Implementation steps

- **Analyze workload elasticity:** Using the hourly granularity in Cost Explorer or a custom dashboard, analyze your workload's elasticity. Look for regular changes in the number of instances that are running. Short duration instances are candidates for Spot Instances or Spot Fleet.
  - [Well-Architected Lab: Cost Explorer](#)
  - [Well-Architected Lab: Cost Visualization](#)
- **Review existing pricing contracts:** Review current contracts or commitments for long term needs. Analyze what you currently have and how much those commitments are in use. Leverage pre-existing contractual discounts or enterprise agreements. [Enterprise Agreements](#) give customers the option to tailor agreements that best suit their needs. For long term commitments, consider reserved pricing discounts, Reserved Instances or Savings Plans for the specific instance type, instance family, AWS Region, and Availability Zones.
- **Perform a commitment discount analysis:** Using Cost Explorer in your account, review the Savings Plans and Reserved Instance recommendations. To verify that you implement the correct recommendations with the required discounts and risk, follow the [Well-Architected labs](#).

## Resources

### Related documents:

- [Accessing Reserved Instance recommendations](#)
- [Instance purchasing options](#)
- [AWS Enterprise](#)

**Related videos:**

- [Save up to 90% and run production workloads on Spot](#)

**Related examples:**

- [Well-Architected Lab: Cost Explorer](#)
- [Well-Architected Lab: Cost Visualization](#)
- [Well-Architected Lab: Pricing Models](#)

## COST07-BP02 Implement Regions based on cost

Resource pricing may be different in each Region. Identify regional cost differences and only deploy in Regions with higher costs to meet latency and data sovereignty requirements. Factoring in Region cost helps you pay the lowest overall price for this workload.

**Level of risk exposed if this best practice is not established:** Medium

### Implementation guidance

When you architect your solutions, a best practice is to seek to place computing resources closer to users to provide lower latency and strong data sovereignty. Select the geographic location based on your business, data privacy, performance, and security requirements. For applications with global end users, use multiple locations.

The [AWS Cloud Infrastructure](#) is global, hosted in [multiple locations world-wide](#), and built around AWS Regions, Availability Zones, Local Zones, AWS Outposts, and Wavelength Zones. A Region is a physical location in the world and each Region is a separate geographic area where AWS has multiple Availability Zones. Availability Zones which are multiple isolated locations within each Region consist of one or more discrete data centers, each with redundant power, networking, and connectivity.

Each AWS Region operates within local market conditions, and resource pricing is different in each Region due to differences in the cost of land, fiber, electricity, and taxes, for example. Choose a specific Region to operate a component of or your entire solution so that you can run at the lowest possible price globally. Use [AWS Calculator](#) to estimate the costs of your workload in various Regions by searching services by location type (Region, wave length zone and local zone) and Region.

Use Regions which provide lower prices for AWS services to deploy your workloads if you have no obligations in data privacy, security and business requirements. For example, if your default Region is ap-southeast-2 (Sydney), and if there are no restrictions (data privacy, security, for example) to use other Regions, deploying non-critical (development and test) Amazon EC2 instances in north-east-1 (N. Virginia) Region will cost you less.

### Implementation steps

- **Review AWS Region pricing:** Analyze the workload costs in the current Region. Starting with the highest costs by service and usage type, calculate the costs in other Regions that are available. If the forecasted saving outweighs the cost of moving the component or workload, migrate to the new Region.
- **Review requirements for multi-Region deployments:** Analyze your business requirements and obligations (data privacy, security, or performance) to find out if there are any restrictions for you to not to use multiple Regions. If there are no obligations to restrict you to use single Region, then use multiple Regions.
- **Analyze required data transfer:** Consider data transfer costs when selecting Regions. Keep your data close to your customer and close to the resources. Select less costly AWS Regions where data flows and

where there is minimal data transfer. Depending on your business requirements for data transfer, you can use [Amazon CloudFront](#), [AWS PrivateLink](#), [AWS Direct Connect](#), and [AWS Virtual Private Network](#) to reduce your networking costs, improve performance, and enhance security.

## Resources

### Related documents:

- [Accessing Reserved Instance recommendations](#)
- [Amazon EC2 pricing](#)
- [Instance purchasing options](#)
- [Region Table](#)

### Related videos:

- [Save up to 90% and run production workloads on Spot](#)

### Related examples:

- [Overview of Data Transfer Costs for Common Architectures](#)
- [Cost Considerations for Global Deployments](#)
- [What to Consider when Selecting a Region for your Workloads](#)
- [Well-Architected Labs: Restrict service usage by Region \(Level 200\)](#)

## COST07-BP03 Select third-party agreements with cost-efficient terms

Cost efficient agreements and terms ensure the cost of these services scales with the benefits they provide. Select agreements and pricing that scale when they provide additional benefits to your organization.

**Level of risk exposed if this best practice is not established:** Medium

## Implementation guidance

When you utilize third-party solutions or services in the cloud, it is important that the pricing structures are aligned to Cost Optimization outcomes. Pricing should scale with the outcomes and value it provides. An example of this is software that takes a percentage of savings it provides, the more you save (outcome) the more it charges. Agreements that scale with your bill are typically not aligned to Cost Optimization, unless they provide outcomes for every part of your specific bill. For example, a solution that provides recommendations for Amazon Elastic Compute Cloud(Amazon EC2) and charges a percentage of your entire bill will increase if you use other services for which it provides no benefit. Another example is a managed service that is charged at a percentage of the cost of resources that are managed. A larger instance size may not necessarily require more management effort, but will be charged more. Ensure that these service pricing arrangements include a cost optimization program or features in their service to drive efficiency.

### Implementation steps

- **Analyze third-party agreements and terms:** Review the pricing in third party agreements. Perform modeling for different levels of your usage, and factor in new costs such as new service usage, or

increases in current services due to workload growth. Decide if the additional costs provide the required benefits to your business.

## Resources

### Related documents:

- [Accessing Reserved Instance recommendations](#)
- [Instance purchasing options](#)

### Related videos:

- [Save up to 90% and run production workloads on Spot](#)

## COST07-BP04 Implement pricing models for all components of this workload

Permanently running resources should utilize reserved capacity such as Savings Plans or Reserved Instances. Short-term capacity is configured to use Spot Instances, or Spot Fleet. On-Demand Instances are only used for short-term workloads that cannot be interrupted and do not run long enough for reserved capacity, between 25% to 75% of the period, depending on the resource type.

**Level of risk exposed if this best practice is not established:** Low

## Implementation guidance

Consider the requirements of the workload components and understand the potential pricing models. Define the availability requirement of the component. Determine if there are multiple independent resources that perform the function in the workload, and what the workload requirements are over time. Compare the cost of the resources using the default On-Demand pricing model and other applicable models. Factor in any potential changes in resources or workload components.

### Implementation steps

- **Implement pricing models:** Using your analysis results, purchase Savings Plans (SPs), Reserved Instances (RIs) or implement Spot Instances. If it is your first RI purchase then choose the top 5 or 10 recommendations in the list, then monitor and analyze the results over the next month or two. Purchase small numbers of commitment discounts regular cycles, for example every two weeks or monthly. Implement Spot Instances for workloads that can be interrupted or are stateless.
- **Workload review cycle:** Implement a review cycle for the workload that specifically analyzes pricing model coverage. Once the workload has the required coverage, purchase additional commitment discounts every two to four weeks, or as your organization usage changes.

## Resources

### Related documents:

- [Accessing Reserved Instance recommendations](#)
- [EC2 Fleet](#)
- [How to Purchase Reserved Instances](#)
- [Instance purchasing options](#)



- [Spot Instances](#)

**Related videos:**

- [Save up to 90% and run production workloads on Spot](#)

## COST07-BP05 Perform pricing model analysis at the management account level

Check billing and cost management tools and see recommended discounts with commitments and reservations to perform regular analysis at the management account level.

**Level of risk exposed if this best practice is not established:** Low

### Implementation guidance

Performing regular cost modeling helps you implement opportunities to optimize across multiple workloads. For example, if multiple workloads use On-Demand Instances, at an aggregate level, the risk of change is lower, and implementing a commitment-based discount will achieve a lower overall cost. It is recommended to perform analysis in regular cycles of two weeks to one month. This allows you to make small adjustment purchases, so the coverage of your pricing models continues to evolve with your changing workloads and their components.

Use the [AWS Cost Explorer](#) recommendations tool to find opportunities for commitment discounts in your management account. Recommendations at the management account level are calculated considering usage across all of the accounts in your AWS organization that have Reserve Instances or Savings Plans (SP) discount sharing activated, to recommend a commitment that maximizes savings across accounts. Member account recommendations are calculated at the individual account level, to maximize savings for each isolated account. You can refresh Savings Plans Recommendations in AWS Cost Management to generate new Savings Plans Recommendations at any time.

After analysing flexibility of instances, you can commit by following recommendations. Create cost modelling with analysing the workload's short-term costs with potential different resource options, analysing AWS pricing models and aligning them with your business requirements to find out total cost of ownership and [cost optimization](#) opportunities.

### Implementation steps

- **Perform a commitment discount analysis:** Using Cost Explorer in your account review the Savings Plans and Reserved Instance recommendations. Make sure you understand Saving Plan recommendations, estimate your monthly spend and estimate your monthly savings. Review recommendations at the management account level which are calculated considering usage across all of the member accounts in your AWS organization that have Reserve Instances or Savings Plans discount sharing activated for maximum savings across accounts. You can ensure you implemented the correct recommendations with the required discounts and risk by following the Well-Architected labs.

### Resources

**Related documents:**

- [How does AWS pricing work?](#)
- [Instance purchasing options](#)
- [Saving Plan Overview](#)



- [Saving Plan recommendations](#)
- [Accessing Reserved Instance recommendations](#)
- [How Savings Plans apply to your AWS usage](#)
- [Savings Plans with Consolidated Billing](#)
- [Turning on shared reserved instances and Savings Plans discounts](#)

**Related videos:**

- [Save up to 90% and run production workloads on Spot](#)

**Related examples:**

- [Well-Architected Lab: Pricing Models \(Level 200\)](#)
- [Well-Architected Labs: Pricing Model Analysis \(Level 200\)](#)
- [What should I consider before purchasing a Savings Plan?](#)
- [How can I use rolling Savings Plans to reduce commitment risk?](#)
- [When to Use Spot Instances](#)

## Plan for data transfer

An advantage of the cloud is that it is a managed network service. There is no longer the need to manage and operate a fleet of switches, routers, and other associated network equipment. Networking resources in the cloud are consumed and paid for in the same way you pay for CPU and storage—you only pay for what you use. Efficient use of networking resources is required for cost optimization in the cloud.

**Best practices**

- [COST08-BP01 Perform data transfer modeling \(p. 69\)](#)
- [COST08-BP02 Select components to optimize data transfer cost \(p. 70\)](#)
- [COST08-BP03 Implement services to reduce data transfer costs \(p. 71\)](#)

## COST08-BP01 Perform data transfer modeling

Gather organization requirements and perform data transfer modeling of the workload and each of its components. This identifies the lowest cost point for its current data transfer requirements.

**Level of risk exposed if this best practice is not established:** High

### Implementation guidance

Understand where the data transfer occurs in your workload, the cost of the transfer, and its associated benefit. This allows you to make an informed decision to modify or accept the architectural decision. For example, you may have a Multi-Availability Zone configuration where you replicate data between the Availability Zones. You model the cost of structure and decide that this is an acceptable cost (similar to paying for compute and storage in both Availability Zone) to achieve the required reliability and resilience.

Model the costs over different usage levels. Workload usage can change over time, and different services may be more cost effective at different levels.

Use [AWS Cost Explorer](#) or the [AWS Cost and Usage Report](#) (CUR) to understand and model your data transfer costs. Configure a proof of concept (PoC) or test your workload, and run a test with a realistic simulated load. You can model your costs at different workload demands.

#### Implementation steps

- **Calculate data transfer costs:** Use the [AWS pricing pages](#) and calculate the data transfer costs for the workload. Calculate the data transfer costs at different usage levels, for both increases and reductions in workload usage. Where there are multiple options for the workload architecture, calculate the cost for each option for comparison.
- **Link costs to outcomes:** For each data transfer cost incurred, specify the outcome that it achieves for the workload. If it is transfer between components, it may be for decoupling, if it is between Availability Zones it may be for redundancy.

## Resources

#### Related documents:

- [AWS caching solutions](#)
- [AWS Pricing](#)
- [Amazon EC2 Pricing](#)
- [Amazon VPC pricing](#)
- [Deliver content faster with Amazon CloudFront](#)

## COST08-BP02 Select components to optimize data transfer cost

All components are selected, and architecture is designed to reduce data transfer costs. This includes using components such as wide-area-network (WAN) optimization and Multi-Availability Zone (AZ) configurations

**Level of risk exposed if this best practice is not established:** Medium

## Implementation guidance

Architecting for data transfer ensures that you minimize data transfer costs. This may involve using content delivery networks to locate data closer to users, or using dedicated network links from your premises to AWS. You can also use WAN optimization and application optimization to reduce the amount of data that is transferred between components.

#### Implementation steps

- **Select components for data transfer:** Using the data transfer modeling, focus on where the largest data transfer costs are or where they would be if the workload usage changes. Look for alternative architectures, or additional components that remove or reduce the need for data transfer, or lower its cost.

## Resources

#### Related documents:

- [AWS caching solutions](#)

- [Deliver content faster with Amazon CloudFront](#)

## COST08-BP03 Implement services to reduce data transfer costs

Implement services to reduce data transfer. For example, using a content delivery network (CDN) such as Amazon CloudFront to deliver content to end users, caching layers using Amazon ElastiCache, or using AWS Direct Connect instead of VPN for connectivity to AWS.

**Level of risk exposed if this best practice is not established:** Medium

### Implementation guidance

[Amazon CloudFront](#) is a global content delivery network that delivers data with low latency and high transfer speeds. It caches data at edge locations across the world, which reduces the load on your resources. By using CloudFront, you can reduce the administrative effort in delivering content to large numbers of users globally, with minimum latency.

[AWS Direct Connect](#) allows you to establish a dedicated network connection to AWS. This can reduce network costs, increase bandwidth, and provide a more consistent network experience than internet-based connections.

[AWS VPN](#) allows you to establish a secure and private connection between your private network and the AWS global network. It is ideal for small offices or business partners because it provides quick and easy connectivity, and it is a fully managed and elastic service.

[VPC Endpoints](#) allow connectivity between AWS services over private networking and can be used to reduce public data transfer and [NAT gateways](#) costs. [Gateway VPC endpoints](#) have no hourly charges, and support Amazon Simple Storage Service (Amazon S3) and Amazon DynamoDB. [Interface VPC endpoints](#) are provided by [AWS PrivateLink](#) and have an hourly fee and per GB usage cost.

### Implementation steps

- **Implement services:** Using the data transfer modeling, look at where the largest costs and highest volume flows are. Review the AWS services and assess whether there is a service that reduces or removes the transfer, specifically networking and content delivery. Also look for caching services where there is repeated access to data, or large amounts of data.

## Resources

### Related documents:

- [AWS Direct Connect](#)
- [AWS Explore Our Products](#)
- [AWS caching solutions](#)
- [Amazon CloudFront](#)
- [Deliver content faster with Amazon CloudFront](#)

# Manage demand and supply resources

When you move to the cloud, you pay only for what you need. You can supply resources to match the workload demand at the time they're needed — eliminating the need for costly and wasteful overprovisioning. You can also modify the demand using a throttle, buffer, or queue to smooth the demand and serve it with less resources.

The economic benefits of just-in-time supply should be balanced against the need to provision to account for resource failures, high availability, and provision time. Depending on whether your demand is fixed or variable, plan to create metrics and automation that will ensure that management of your environment is minimal – even as you scale. When modifying the demand, you must know the acceptable and maximum delay that the workload can allow.

In AWS, you can use a number of different approaches for managing demand and supplying resources. The following best practices describe how to use these approaches.

## Best practices

- [COST09-BP01 Perform an analysis on the workload demand \(p. 72\)](#)
- [COST09-BP02 Implement a buffer or throttle to manage demand \(p. 73\)](#)
- [COST09-BP03 Supply resources dynamically \(p. 74\)](#)

## COST09-BP01 Perform an analysis on the workload demand

Analyze the demand of the workload over time. Verify that the analysis covers seasonal trends and accurately represents operating conditions over the full workload lifetime. Analysis effort should reflect the potential benefit, for example, time spent is proportional to the workload cost.

**Level of risk exposed if this best practice is not established:** High

## Implementation guidance

Know the requirements of the workload. The organization requirements should indicate the workload response times for requests. The response time can be used to determine if the demand is managed, or if the supply of resources will change to meet the demand.

The analysis should include the predictability and repeatability of the demand, the rate of change in demand, and the amount of change in demand. Ensure that the analysis is performed over a long enough period to incorporate any seasonal variance, such as end-of-month processing or holiday peaks.

Ensure that the analysis effort reflects the potential benefits of implementing scaling. Look at the expected total cost of the component, and any increases or decreases in usage and cost over the workload lifetime.

You can use [AWS Cost Explorer](#) or [Amazon QuickSight](#) with the AWS Cost and Usage Report (CUR) or your application logs to perform a visual analysis of workload demand.

### Implementation steps

- **Analyze existing workload data:** Analyze data from the existing workload, previous versions of the workload, or predicted usage patterns. Use log files and monitoring data to gain insight on how customers use the workload. Typical metrics are the actual demand in requests per second, the times when the rate of demand changes or when it is at different levels, and the rate of change of demand. Ensure you analyze a full cycle of the workload, ensuring you collect data for any seasonal changes such as end of month or end of year events. The effort reflected in the analysis should reflect the workload characteristics. The largest effort should be placed on high-value workloads that have the largest changes in demand. The least effort should be placed on low-value workloads that have minimal changes in demand. Common metrics for value are risk, brand awareness, revenue or workload cost.
- **Forecast outside influence:** Meet with team members from across the organization that can influence or change the demand in the workload. Common teams would be sales, marketing, or business development. Work with them to know the cycles they operate within, and if there are any events that would change the demand of the workload. Forecast the workload demand with this data.

## Resources

### Related documents:

- [AWS Auto Scaling](#)
- [AWS Instance Scheduler](#)
- [Getting started with Amazon SQS](#)
- [AWS Cost Explorer](#)
- [Amazon QuickSight](#)

## COST09-BP02 Implement a buffer or throttle to manage demand

Buffering and throttling modify the demand on your workload, smoothing out any peaks. Implement throttling when your clients perform retries. Implement buffering to store the request and defer processing until a later time. Verify that your throttles and buffers are designed so clients receive a response in the required time.

**Level of risk exposed if this best practice is not established:** Medium

## Implementation guidance

**Throttling:** If the source of the demand has retry capability, then you can implement throttling. Throttling tells the source that if it cannot service the request at the current time it should try again later. The source will wait for a period of time and then re-try the request. Implementing throttling has the advantage of limiting the maximum amount of resources and costs of the workload. In AWS, you can use [Amazon API Gateway](#) to implement throttling. Refer to the [Well-Architected Reliability pillar whitepaper](#) for more details on implementing throttling.

**Buffer based:** Similar to throttling, a buffer defers request processing, allowing applications that run at different rates to communicate effectively. A buffer-based approach uses a queue to accept messages (units of work) from producers. Messages are read by consumers and processed, allowing the messages to run at the rate that meets the consumers' business requirements. You don't have to worry about producers having to deal with throttling issues, such as data durability and backpressure (where producers slow down because their consumer is running slowly).

In AWS, you can choose from multiple services to implement a buffering approach. [Amazon Simple Queue Service \(Amazon SQS\)](#) is a managed service that provides queues that allow a single consumer to read individual messages. [Amazon Kinesis](#) provides a stream that allows many consumers to read the same messages.

When architecting with a buffer-based approach, ensure that you architect your workload to service the request in the required time, and that you are able to handle duplicate requests for work.

#### Implementation steps

- **Analyze the client requirements:** Analyze the client requests to determine if they are capable of performing retries. For clients that cannot perform retries, buffers will need to be implemented. Analyze the overall demand, rate of change, and required response time to determine the size of throttle or buffer required.
- **Implement a buffer or throttle:** Implement a buffer or throttle in the workload. A queue such as Amazon Simple Queue Service (Amazon SQS) can provide a buffer to your workload components. Amazon API Gateway can provide throttling for your workload components.

## Resources

#### Related documents:

- [AWS Auto Scaling](#)
- [AWS Instance Scheduler](#)
- [Amazon API Gateway](#)
- [Amazon Simple Queue Service](#)
- [Getting started with Amazon SQS](#)
- [Amazon Kinesis](#)

## COST09-BP03 Supply resources dynamically

Resources are provisioned in a planned manner. This can be demand-based, such as through automatic scaling, or time-based, where demand is predictable and resources are provided based on time. These methods result in the least amount of over or under-provisioning.

**Level of risk exposed if this best practice is not established:** Low

## Implementation guidance

You can use [AWS Auto Scaling](#), or incorporate scaling in your code with the [AWS API or SDKs](#). This reduces your overall workload costs by removing the operational cost from manually making changes to your environment, and can be performed much faster. This also matches your workload resourcing to your demand at any time. In order to follow this best practice and supply resources dynamically for your organization, you should understand horizontal and vertical scaling in the AWS Cloud as well as the nature of the applications running on Amazon EC2 instances. It is better for your Cloud Financial Management team to work with technical teams to follow this best practice.

[AWS Instance Scheduler](#) allows you to configure the stop and start of your Amazon EC2 and Amazon RDS instances at defined times so that you can meet the demand for the same resources within a consistent time pattern such as every day user access Amazon EC2 instances at eight in the morning that they don't need after six at night. This solution helps reduce operational cost by stopping resources that are not in use and starting them when they are needed.

You can schedule Amazon EC2 or Amazon RDS instances with AWS Instance Scheduler. However, you cannot stop and start instances which are part of your Auto Scaling group (ASG) or that manage services such as Amazon Redshift or Amazon OpenSearch Service. Auto Scaling groups have their own scheduling for the instances in the group and these instances are created. On the other hand, Instance Scheduler stops and starts existing instances. We will group Auto Scaling groups into two categories and deep dive into each one of them.

**Demand-based supply:** Leverage the elasticity of the cloud to supply resources to meet changing demand. Take advantage of APIs or service features to programmatically vary the amount of cloud resources in your architecture dynamically. This allows you to scale components in your architecture, and automatically increase the number of resources during demand spikes to maintain performance, and decrease capacity when demand subsides to reduce costs.

[AWS Auto Scaling](#) helps you adjust your capacity to maintain steady, predictable performance at the lowest possible cost. It is a fully managed and free service that integrates with Amazon Elastic Compute Cloud instances and Spot Fleets, Amazon Elastic Container Service, Amazon DynamoDB, and Amazon Aurora. Auto Scaling provides automatic resource discovery to help find resources in your workload that can be configured, it has built-in scaling strategies to optimize performance, costs or a balance between the two, and provides predictive scaling to assist with regularly occurring spikes.

Auto Scaling can implement manual, scheduled or demand-based scaling. You can also use metrics and alarms from [Amazon CloudWatch](#) to launch scaling events for your workload. Typical metrics can be standard Amazon EC2 metrics, such as CPU utilization, network throughput, and [Elastic Load Balancing\(ELB\)](#) observed request or response latency. When possible, you should use a metric that is indicative of customer experience, which is typically a custom metric that might originate from application code within your workload.

When architecting with a demand-based approach keep in mind two key considerations. First, understand how quickly you must provision new resources. Second, understand that the size of margin between supply and demand will shift. You must be ready to cope with the rate of change in demand and also be ready for resource failures.

[Elastic Load Balancing](#) helps you to scale by distributing demand across multiple resources. As you implement more resources, you add them to the load balancer to take on the demand. Elastic Load Balancing has support for Amazon EC2 Instances, containers, IP addresses, and AWS Lambda functions.

**Time-based supply:** A time-based approach aligns resource capacity to demand that is predictable or well-defined by time. This approach is typically not dependent upon utilization levels of the resources. A time-based approach ensures that resources are available at the specific time they are required and can be provided without any delays due to start-up procedures and system or consistency checks. Using a time-based approach, you can provide additional resources or increase capacity during busy periods.

You can use scheduled Auto Scaling to implement a time-based approach. Workloads can be scheduled to scale out or in at defined times (for example, the start of business hours), making resources available when users arrive or demand increases. Predictive scaling uses patterns to scale out while scheduled scaling uses pre-defined times to scale out. You can also use attribute-based instance type selection (ABS) strategy in Auto Scaling groups, which lets you express your instance requirements as a set of attributes, such as vCPU, memory, and storage. This also allows you to automatically use newer generation instance types when they are released and access a broader range of capacity with Amazon EC2 Spot Instances. Amazon EC2 Fleet and Amazon EC2 Auto Scaling select and launch instances that fit the specified attributes, removing the need to manually pick instance types.

You can also leverage the [AWS APIs and SDKs](#) and [AWS CloudFormation](#) to automatically provision and decommission entire environments as you need them. This approach is well suited for development or test environments that run only in defined business hours or periods of time. You can use APIs to scale the size of resources within an environment (vertical scaling). For example, you could scale up a production workload by changing the instance size or class. This can be achieved by stopping and starting the instance and selecting the different instance size or class. This technique can also be applied

to other resources, such as Amazon EBS Elastic Volumes, which can be modified to increase size, adjust performance (IOPS) or change the volume type while in use.

When architecting with a time-based approach keep in mind two key considerations. First, how consistent is the usage pattern? Second, what is the impact if the pattern changes? You can increase the accuracy of predictions by monitoring your workloads and by using business intelligence. If you see significant changes in the usage pattern, you can adjust the times to ensure that coverage is provided.

### Implementation steps

- **Configure scheduled scaling:** For predictable changes in demand, time-based scaling can provide the correct number of resources in a timely manner. It is also useful if resource creation and configuration is not fast enough to respond to changes on demand. Using the workload analysis configure scheduled scaling using AWS Auto Scaling. To configure time-based scheduling, you can use predictive scaling of scheduled scaling to increase the number of Amazon EC2 instances in your Auto Scaling groups in advance according to expected or predictable load changes.
- **Configure predictive scaling:** Predictive scaling allows you to increase the number of Amazon EC2 instances in your Auto Scaling group in advance of daily and weekly patterns in traffic flows. If you have regular traffic spikes and applications that take a long time to start, you should consider using predictive scaling. Predictive scaling can help you scale faster by initializing capacity before projected load compared to dynamic scaling alone, which is reactive in nature. For example, if users start using your workload with the start of the business hours and don't use after hours, then predictive scaling can add capacity before the business hours which eliminates delay of dynamic scaling to react to changing traffic.
- **Configure dynamic automatic scaling:** To configure scaling based on active workload metrics, use Auto Scaling. Use the analysis and configure Auto Scaling to launch on the correct resource levels, and verify that the workload scales in the required time. You can launch and automatically scale a fleet of On-Demand Instances and Spot Instances within a single Auto Scaling group. In addition to receiving discounts for using Spot Instances, you can use Reserved Instances or a Savings Plan to receive discounted rates of the regular On-Demand Instance pricing. All of these factors combined help you to optimize your cost savings for Amazon EC2 instances and help you get the desired scale and performance for your application.

## Resources

### Related documents:

- [AWS Auto Scaling](#)
- [AWS Instance Scheduler](#)
- [Scale the size of your Auto Scaling group](#)
- [Getting Started with Amazon EC2 Auto Scaling](#)
- [Getting started with Amazon SQS](#)
- [Scheduled Scaling for Amazon EC2 Auto Scaling](#)
- [Predictive scaling for Amazon EC2 Auto Scaling](#)

### Related videos:

- [Target Tracking Scaling Policies for Auto Scaling](#)
- [AWS Instance Scheduler](#)

### Related examples:

- [Attribute based Instance Type Selection for Auto Scaling for Amazon EC2 Fleet](#)



- [Optimizing Amazon Elastic Container Service for cost using scheduled scaling](#)
- [Predictive Scaling with Amazon EC2 Auto Scaling](#)
- [How do I use Instance Scheduler with AWS CloudFormation to schedule Amazon EC2 instances?](#)

# Optimize over time

In AWS, you optimize over time by reviewing new services and implementing them in your workload.

As AWS releases new services and features, it is a best practice to review your existing architectural decisions to ensure that they remain cost effective. As your requirements change, be aggressive in decommissioning resources, components, and workloads that you no longer require. Consider the following best practices to help you optimize over time.

While optimizing your workloads over time and improving your [CFM](#) culture in your organization, evaluate the cost of effort for operations in the cloud, review your time-consuming cloud operations, and automate them to reduce human efforts and cost by adopting related AWS services, third party products, or custom tools (like [AWS CLI](#) or [AWS SDKs](#)).

## Topics

- [Define a review process and analyze your workload regularly \(p. 78\)](#)
- [Automating operations \(p. 81\)](#)

## Define a review process and analyze your workload regularly

### Best practices

- [COST10-BP01 Develop a workload review process \(p. 78\)](#)
- [COST10-BP02 Review and analyze this workload regularly \(p. 80\)](#)

## COST10-BP01 Develop a workload review process

Develop a process that defines the criteria and process for workload review. The review effort should reflect potential benefit. For example, core workloads or workloads with a value of over ten percent of the bill are reviewed quarterly or every six months, while workloads below ten percent are reviewed annually.

**Level of risk exposed if this best practice is not established:** High

### Implementation guidance

To have the most cost-efficient workload, you must regularly review the workload to know if there are opportunities to implement new services, features, and components. To achieve overall lower costs the process must be proportional to the potential amount of savings. For example, workloads that are 50% of your overall spend should be reviewed more regularly, and more thoroughly, than workloads that are five percent of your overall spend. Factor in any external factors or volatility. If the workload services a specific geography or market segment, and change in that area is predicted, more frequent reviews could lead to cost savings. Another factor in review is the effort to implement changes. If there are significant costs in testing and validating changes, reviews should be less frequent.

Factor in the long-term cost of maintaining outdated and legacy, components and resources and the inability to implement new features into them. The current cost of testing and validation may exceed

the proposed benefit. However, over time, the cost of making the change may significantly increase as the gap between the workload and the current technologies increases, resulting in even larger costs. For example, the cost of moving to a new programming language may not currently be cost effective. However, in five years time, the cost of people skilled in that language may increase, and due to workload growth, you would be moving an even larger system to the new language, requiring even more effort than previously.

Break down your workload into components, assign the cost of the component (an estimate is sufficient), and then list the factors (for example, effort and external markets) next to each component. Use these indicators to determine a review frequency for each workload. For example, you may have web servers as a high cost, low change effort, and high external factors, resulting in high frequency of review. A central database may be medium cost, high change effort, and low external factors, resulting in a medium frequency of review.

Define a process to evaluate new services, design patterns, resource types, and configurations to optimize your workload cost as they become available. Similar to [performance pillar review](#) and [reliability pillar review](#) processes, identify, validate, and prioritize optimization and improvement activities and issue remediation and incorporate this into your backlog.

### Implementation steps

- **Define review frequency:** Define how frequently the workload and its components should be reviewed. Allocate time and resources to continual improvement and review frequency to improve the efficiency and optimization of your workload. This is a combination of factors and may differ from workload to workload within your organization and between components in the workload. Common factors include the importance to the organization measured in terms of revenue or brand, the total cost of running the workload (including operation and resource costs), the complexity of the workload, how easy is it to implement a change, any software licensing agreements, and if a change would incur significant increases in licensing costs due to punitive licensing. Components can be defined functionally or technically, such as web servers and databases, or compute and storage resources. Balance the factors accordingly and develop a period for the workload and its components. You may decide to review the full workload every 18 months, review the web servers every six months, the database every 12 months, compute and short-term storage every six months, and long-term storage every 12 months.
- **Define review thoroughness:** Define how much effort is spent on the review of the workload or workload components. Similar to the review frequency, this is a balance of multiple factors. Evaluate and prioritize opportunities for improvement to focus efforts where they provide the greatest benefits while estimating how much effort is required for these activities. If the expected outcomes do not satisfy the goals, and required effort costs more, then iterate using alternative courses of action. Your review processes should include dedicated time and resources to make continuous incremental improvements possible. As an example, you may decide to spend one week of analysis on the database component, one week of analysis for compute resources, and four hours for storage reviews.

## Resources

### Related documents:

- [AWS News Blog](#)
- [Types of Cloud Computing](#)
- [What's New with AWS](#)

### Related examples:

- [AWS Support Proactive Services](#)
- [Regular workload reviews for SAP workloads](#)

## COST10-BP02 Review and analyze this workload regularly

Existing workloads are regularly reviewed based on each defined process to find out if new services can be adopted, existing services can be replaced, or workloads can be re-architected.

**Level of risk exposed if this best practice is not established:** Medium

### Implementation guidance

AWS is constantly adding new features so you can experiment and innovate faster with the latest technology. [AWS What's New](#) details how AWS is doing this and provides a quick overview of AWS services, features, and Regional expansion announcements as they are released. You can dive deeper into the launches that have been announced and use them for your review and analyze of your existing workloads. To realize the benefits of new AWS services and features, you review on your workloads and implement new services and features as required. This means you may need to replace existing services you use for your workload, or modernize your workload to adopt these new AWS services. For example, you might review your workloads and replace the messaging component with Amazon Simple Email Service. This removes the cost of operating and maintaining a fleet of instances, while providing all the functionality at a reduced cost.

To analyze your workload and highlight potential opportunities, you should consider not only new services but also new ways of building solutions. Review the [This is My Architecture](#) videos on AWS to learn about other customers' architecture designs, their challenges and their solutions. Check the [All-In series](#) to find out real world applications of AWS services and customer stories. You can also watch the [Back to Basics](#) video series that explains, examines, and breaks down basic cloud architecture pattern best practices. Another source is [How to Build This](#) videos, which are designed to assist people with big ideas on how to bring their minimum viable product (MVP) to life using AWS services. It is a way for builders from all over the world who have a strong idea to gain architectural guidance from experienced AWS Solutions Architects. Finally, you can review the [Getting Started](#) resource materials, which has step by step tutorials.

Before starting your review process, follow your business' requirements for the workload, security and data privacy requirements in order to use specific service or Region and performance requirements while following your agreed review process.

### Implementation steps

- **Regularly review the workload:** Using your defined process, perform reviews with the frequency specified. Verify that you spend the correct amount of effort on each component. This process would be similar to the initial design process where you selected services for cost optimization. Analyze the services and the benefits they would bring, this time factor in the cost of making the change, not just the long-term benefits.
- **Implement new services:** If the outcome of the analysis is to implement changes, first perform a baseline of the workload to know the current cost for each output. Implement the changes, then perform an analysis to confirm the new cost for each output.

## Resources

### Related documents:

- [AWS News Blog](#)
- [What's New with AWS](#)
- [AWS Documentation](#)
- [AWS Getting Started](#)

- [AWS General Resources](#)

**Related videos:**

- [AWS - This is My Architecture](#)
- [AWS - Back to Basics](#)
- [AWS - All-In series](#)
- [How to Build This](#)

## Automating operations

**Best practices**

- [COST11-BP01 Perform automations for operations \(p. 81\)](#)

### COST11-BP01 Perform automations for operations

Evaluate cost of effort for operations on cloud. Quantify reduction in time and effort for admin tasks, deployment and other operations using automation. Evaluate the required time and cost for the effort of operations and automate admin tasks to reduce the human effort where possible.

**Level of risk exposed if this best practice is not established: Low**

Automating operations improves consistency and scalability, provides more visibility, reliability, and flexibility, reduces costs, and accelerates innovation by freeing up human resources and improving metrics. It reduces the frequency of manual tasks, improves efficiency, and benefits enterprises by delivering a consistent and reliable experience when deploying, administering, or operating workloads. You can free up infrastructure resources from manual operational tasks and use them for higher value tasks and innovations, thereby improving business outcomes. Enterprises require a proven, tested way to manage their workloads in the cloud. That solution must be secure, fast, and cost effective, with minimum risk and maximum reliability.

Start by prioritizing your operations based on required effort by looking at overall operations cost in the cloud. For example, how long does it take to deploy new resources in the cloud, make optimization changes to existing ones, or implement necessary configurations? Look at the total cost of human actions by factoring in cost of operations and management. Prioritize automations for admin tasks to reduce the human effort. Review effort should reflect the potential benefit. For example, time spent performing tasks manually as opposed to automatically. Prioritize automating repetitive, high value activities. Activities that pose a higher risk of human error are typically the better place to start automating as the risk often poses an unwanted additional operational cost (like operations team working extra hours).

Using AWS services, tools, or third-party products, you can choose which AWS automations to implement and customize for your specific requirements. The following table shows some of the core operation functions and capabilities you can achieve with AWS services to automate administration and operation:

- [AWS Audit Manager](#): Continually audit your AWS usage to simplify risk and compliance assessment
- [AWS Backup](#): Centrally manage and automate data protection.
- [AWS Config](#): Configure compute resources, assess, audit, and evaluate configurations and resource inventory.
- [AWS CloudFormation](#): Launch highly available resources with infrastructure as code.
- [AWS CloudTrail](#): IT change management, compliance, and control.
- [Amazon EventBridge](#): Schedule events and launch AWS Lambda to take action.

- [AWS Lambda](#): Automate repetitive processes by initiating them with events or by running them on a fixed schedule with Amazon EventBridge.
- [AWS Systems Manager](#): Start and stop workloads, patch operating systems, automate configuration, and ongoing management.
- [AWS Step Functions](#): Schedule jobs and automate workflows.
- [AWS Service Catalog](#): Template consumption and infrastructure as code with compliance and control.

Consider the time savings that will allow your team to focus on retiring technical debt, innovation, and value-adding features. For example, you might need to lift and shift your on-premises environment into the cloud as rapidly as possible and optimize later. It is worth exploring the savings you could realize by using fully managed services by AWS that remove or reduce license costs such as [Amazon Relational Database Service](#), [Amazon EMR](#), [Amazon WorkSpaces](#), and [Amazon SageMaker](#). Managed services remove the operational and administrative burden of maintaining a service, which allows you to focus on innovation. Additionally, because managed services operate at cloud scale, they can offer a lower cost per transaction or service.

If you would like to adopt automations immediately with using AWS products and service and if don't have skills in your organization, reach out to [AWS Managed Services \(AMS\)](#), [AWS Professional Services](#), or [AWS Partners](#) to increase adoption of automation and improve your operational excellence in the cloud.

[AWS Managed Services \(AMS\)](#) is a service that operates AWS infrastructure on behalf of enterprise customers and partners. It provides a secure and compliant environment that you can deploy your workloads onto. AMS uses enterprise cloud operating models with automation to allow you to meet your organization requirements, move into the cloud faster, and reduce your on-going management costs.

[AWS Professional Services](#) can also help you achieve your desired business outcomes and automate operations with AWS. AWS Professional Services provides global specialty practices to support your efforts in focused areas of enterprise cloud computing. Specialty practices deliver targeted guidance through best practices, frameworks, tools, and services across solution, technology, and industry subject areas. They help customers to deploy automated, robust, agile IT operations, and governance capabilities optimized for the cloud center.

### Implementation steps

- **Build once and deploy many:** Use infrastructure-as-code such as AWS CloudFormation, AWS SDK, or AWS Command Line Interface (AWS CLI) to deploy once and use many times for same environment or for disaster recovery scenarios. Tag while deploying to track your consumption as defined in other best practices. Use [AWS Launch Wizard](#) to reduce the time to deploy many popular enterprise workloads. AWS Launch Wizard guides you through the sizing, configuration, and deployment of enterprise workloads following AWS best practices. You can also use the [AWS Service Catalog](#), which helps you create and manage infrastructure-as-code approved templates for use on AWS so anyone can discover approved, self-service cloud resources.
- **Automate operations:** Run routine operations automatically without human intervention. Using AWS services and tools, you can choose which AWS automations to implement and customize for your specific requirements. For example, use [EC2 Image Builder](#) for building, testing, and deployment of virtual machine and container images for use on AWS or on-premises. If your desired action cannot be done with AWS services or you need more complex actions with filtering resources, then automate your operations with using [AWS CLI](#) or AWS SDK tools. AWS CLI provides the ability to automate the entire process of controlling and managing AWS services via scripts without using the AWS Console. Select your preferred AWS SDKs to interact with AWS services. For other code examples, see [AWS SDK Code examples repository](#).

## Resources

### Related documents:

- [Modernizing operations in the AWS Cloud](#)
- [AWS Services for Automation](#)
- [AWS Systems Manager Automation](#)
- [AWS automations for SAP administration and operations](#)
- [AWS Managed Services](#)
- [AWS Professional Services](#)
- [Infrastructure and automation](#)

**Related examples:**

- [Reinventing automated operations \(Part I\)](#)
- [Reinventing automated operations \(Part II\)](#)
- [AWS automations for SAP administration and operations](#)
- [IT Automations with AWS Lambda](#)
- [AWS Code Examples Repository](#)
- [AWS Samples](#)

# Conclusion

Cost optimization and Cloud Financial Management is an ongoing effort. You should regularly work with your finance and technology teams, review your architectural approach, and update your component selection.

AWS strives to help you minimize cost while you build highly resilient, responsive, and adaptive deployments. To truly optimize the cost of your deployment, take advantage of the tools, techniques, and best practices discussed in this paper.



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# Further reading

For additional information, see:

- [AWS Well-Architected Framework](#)
- [AWS Architecture Center](#)

# Document revisions

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Change	Description	Date
<a href="#">Updates for new Framework (p. 87)</a>	Best practices updated with prescriptive guidance and new best practices added. Question COST 11 added with new best practice COST11-BP01.	April 10, 2023
<a href="#">Minor update (p. 59)</a>	Missing guidance restored to the pricing model section.	January 13, 2023
<a href="#">Whitepaper updated (p. 87)</a>	Best practices updated with new implementation guidance.	December 15, 2022
<a href="#">Whitepaper updated (p. 87)</a>	Best practices expanded and improvement plans added.	October 20, 2022
<a href="#">Minor update (p. 1)</a>	Added Sustainability Pillar to introduction.	December 2, 2021
<a href="#">Minor update (p. 87)</a>	Updated links.	April 25, 2021
<a href="#">Minor update (p. 87)</a>	Updated links.	March 10, 2021
<a href="#">Updates for new Framework (p. 87)</a>	Updated to incorporate CFM, new services, and integration with the Well-Architected too.	July 8, 2020
<a href="#">Whitepaper updated (p. 87)</a>	Updated to reflect changes to AWS and incorporate learnings from reviews with customers.	July 1, 2018
<a href="#">Whitepaper updated (p. 87)</a>	Updated to reflect changes to AWS and incorporate learnings from reviews with customers.	November 1, 2017
<a href="#">Initial publication (p. 87)</a>	Cost Optimization Pillar - AWS Well-Architected Framework published.	November 1, 2016

# Notices

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# AWS glossary

For the latest AWS terminology, see the [AWS glossary](#) in the *AWS General Reference*.