

**GreenTech Maturity Assessment**

**Analysis Report**

**Assessment Details**

|  |  |
| --- | --- |
| Date of Assessment | **27 December 2024** |
| Project Name | **Platform Engineering** |
| Company Name | **Tata Consultancy Services (TCS)** |
| Version | **1.0** |
| Cloud Provider | **AWS** |

**Current Maturity Level**

 **‎ Processes are standardized, documented, well understood and reviewed.**

**GreenTech Maturity Levels**

|  |  |  |
| --- | --- | --- |
| Maturity Levels | Score | Description |
| **Level 1** | **1** | **Processes are unpredictable, poorly controlled, and reactive at best.** |
| **Level 2** | **2** | **Per-project processes. Often still reactive.** |
| **Level 3** | **3** | **Processes are standardized, documented, well understood and reviewed.** |
| **Level 4** | **4** | **Processes are measured and controlled.** |
| **Level 5** | **5** | **Continuous improvement occurs based on quantitative feedback.** |

**Areas Implemented**

|  |  |
| --- | --- |
| Phases | Count |
| **Development** | **4 of 24** |
| **Network** | **1 of 2** |
| **Deployment** | **7 of 19** |
| **Design** | **0 of 31** |
| **Storage** | **0 of 5** |
| **Quality** | **0 of 8** |
| **Operations** | **0 of 12** |

**Recommendations**

**Development:**

1. **Optimize source code for energy and carbon emissions using static code analysis**

|  |  |
| --- | --- |
| Issue Type | Count |
| **Avoid usage of static collections.** | **87** |
| **Avoid multiple if-else statement** | **61** |
| **Do not call a function when declaring a for-type loop** | **54** |
| **Use ++i instead of i++** | **43** |
| **String Builder** | **29** |
| **Avoid getting the size of the collection in the loop** | **23** |
| **Avoid creating and starting threads directly** | **17** |
| **Avoid using Pattern.compile() in a non-static context** | **11** |
| **Free** Resources | **2** |
| **Use System.**arraycopy **to copy arrays** | **1** |

1. **Memory and energy utilization of docker and multi-stage docker files**

|  |  |  |
| --- | --- | --- |
| Metrics | Single-Stage Docker File | Multi-Stage Docker File |
| **Energy Usage** | **High** | **Low** |
| **Build Time** | **5 minutes** | **6 minutes** |
| **Layer Count** | **12 layers** | **8 layers** |
| **Image Size** | **2.06 GB** | **2.01 GB** |
| **Cache Efficiency** | **Low** | **High** |
| **CI/CD Impact** | **High resource usage** | **Optimized resource usage** |

**Adopt Multi-Stage Docker Files:**

* Reduce memory and energy consumption during build and runtime.
* Smaller image sizes lead to faster deployments and lower storage needs.

**Optimize Base Images:**

* Use official, slim, or alpine versions of base images to minimize size.
* Periodically review and update base images to leverage newer, more efficient versions.

**Minimize Dependency Installation:**

* Only install necessary dependencies to reduce build and runtime resource usage.
* Use tools like pip-compile to manage dependencies efficiently.

**Leverage Caching:**

* Utilize Docker's build cache to skip unchanged layers during rebuilds.
* Implement caching for dependencies (e.g., using a proxy server for pip dependencies).

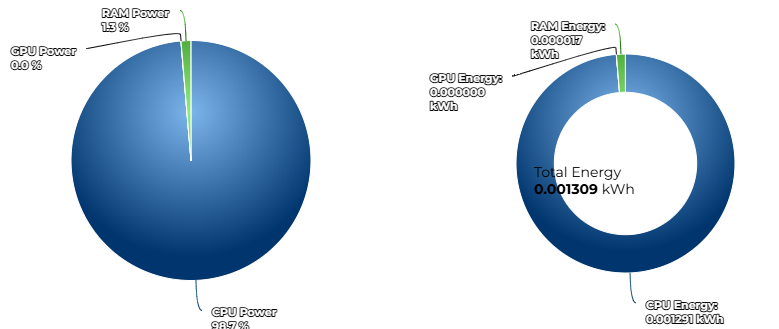
**Monitor and Analyze Resource Usage:**

* Employ tools (e.g., Docker Stats, Prometheus, Grafana) to monitor container resource utilization.
* Analyze findings to identify optimization opportunities.

1. **Energy metrics for application using Intel RAPL, Kepler, Schaphandre**

|  |  |
| --- | --- |
| **CPU Model** | **Intel(R) Xeon(R) Platinum 8259CL CPU @ 2.50GHz** |
| **CPU Count** | **2** |
| **GPU Model** | **N/A** |
| **GPU Count** | **N/A** |
| **RAM** | **3.74 GB** |
| **OS** | **Linux** |
| **Country** | **United States** |
| **Region** | **Virginia** |

|  |  |  |  |
| --- | --- | --- | --- |
| Duration | Energy Consumed | Emissions | Emissions Rate |
| **44.28 Seconds** | **0.001309 Kwh** | **0.000483 kg** | **0.00001091 kg/s** |



**Monitor and Optimize:** Regularly collect energy metrics to identify optimization opportunities in your application.

**Set Sustainability Goals:** Establish targets for your Sustainability Score (SS) or individual energy metrics to drive improvement.

**Energy-Aware Scheduling:** Utilize Kepler to schedule workflow tasks during periods of low energy demand or when renewable energy sources are available.

**Hardware/Software Co-Optimization:** Collaborate with hardware teams to optimize system configurations for improved energy efficiency.

**Continuously Update and Refine:** As new energy-efficient technologies and methodologies emerge, incorporate them into your application and workflows.

1. **Energy consumption of ML job, Model training**

**Optimize Model Architecture:**

* Use efficient neural network architectures (e.g., MobileNet, SqueezeNet, EfficientNet) that require less computational resources.
* Apply model pruning, knowledge distillation, or quantization to reduce model size and computational requirements.

**Select Energy-Efficient Hardware:**

* Utilize GPU accelerators with high performance-per-watt ratios (e.g., NVIDIA Ampere or AMD CDNA).
* Consider TPU (Tensor Processing Unit)-based solutions for large-scale ML workloads.
* Explore FPGA (Field-Programmable Gate Array)-based accelerators for customized, energy-efficient computations.

**Efficient Training Methodologies:**

* Employ transfer learning to fine-tune pre-trained models, reducing training time and energy.
* Use early stopping techniques to halt training when satisfactory performance is achieved.
* Apply distributed training with optimized parallelization to minimize overall training time.

**Data Efficiency:**

* Use smaller, representative datasets for training, reducing computational requirements.
* Apply data augmentation to artificially increase dataset size without adding new samples.

**Hyperparameter Tuning and Automation:**

* Utilize hyperparameter tuning tools (e.g., Hyperopt, Optuna) to quickly identify optimal configurations.
* Implement automated ML (AutoML) pipelines to streamline the training process and minimize unnecessary computations.

**Network:**

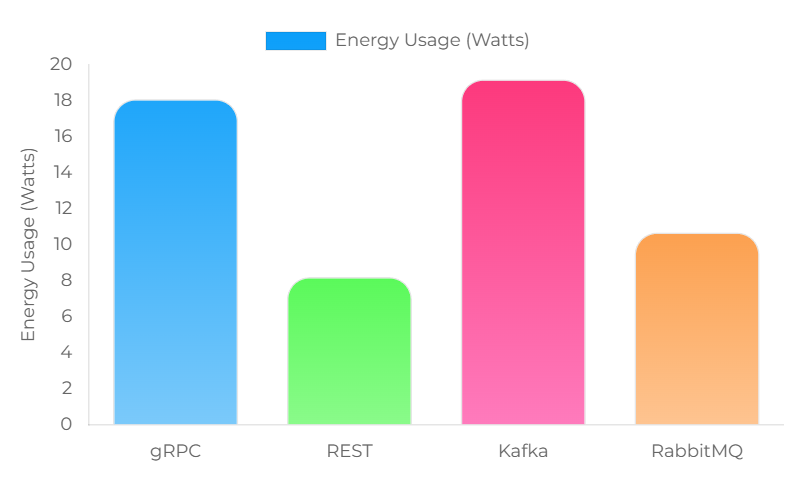
1. **Energy efficiency for synchronous (REST vs gRPC) and Asynchronous (Kafka vs RabbitMQ) messaging between microservices**

**Synchronous Communication Protocols**

|  |  |  |
| --- | --- | --- |
| **Metrics** | **gRPC** | **Rest** |
| **Energy Usage** | **18.1 W** | **8.2 W** |
| **Peak Memory** | **4.45 MB** | **8 MB** |
| **Time Taken** | **3 Minutes** | **4 Min 50 Sec** |
| **Requests** | **500K** | **500K** |
| **Peak CPU** | **10%** | **4%** |

**Asynchronous Communication Protocols**

|  |  |  |
| --- | --- | --- |
| **Metrics** | **Kafka** | **RabbitMQ** |
| **Energy Usage** | **19.2 W** | **10.68 W** |
| **Peak Memory** | **1024 MB** | **512 MB** |
| **Message Rate** | **1M msg/s** | **50K msg/s** |
| **Latency** | **10ms** | **5ms** |
| **CPU Usage** | **55%** | **35%** |



**For Synchronous Messaging (REST/gRPC)**

**Use gRPC for New Developments:**

* Leverage its inherent efficiency advantages, especially for microservices with high inter-service communication.

**Migrate REST to HTTP/2:**

* If moving to gRPC isn’t feasible, ensure REST services use HTTP/2 for some efficiency gains.

**Optimize Payloads:**

* Use efficient serialization formats (e.g., protobuf for gRPC, consider alternatives for REST).
* Implement compression (if not already done).

**Service Discovery and Load Balancing:**

* Ensure efficient routing to reduce unnecessary network hops.

**For Asynchronous Messaging (Kafka/RabbitMQ)**

**Choose Kafka for High-Volume Scenarios:**

* Prefer Kafka when dealing with high throughput and low-latency requirements.

**Optimize RabbitMQ Configurations:**

* For existing RabbitMQ setups, review and optimize configurations for batching, compression, and efficient queue management.

**Leverage Distributed Capabilities:**

* For both Kafka and RabbitMQ, ensure distributed setups are optimized to minimize energy consumption.

**Deployment:**

1. **Tagging of resources to track usage**

**Mandatory Tags:**

* Owner (e.g., team, department, individual)
* Environment (e.g., dev, staging, prod)
* Project/Service (e.g., project name, service identifier)
* Cost Center (e.g., budget code, department ID)

**Optional Tags (as needed):**

* Application
* Component
* Lifecycle (e.g., temporary, permanent)
* Compliance (e.g., PCI, HIPAA)

**Tagging Best Practices:**

* Use Meaningful Names: Clearly indicate the tag's purpose.
* Keep it Concise: Short tag names (< 20 characters) for easier management.
* Avoid Duplication: Use a single tag for a specific attribute (e.g., don't use both Env and Environment).
* Use Consistent Formatting: Establish a standard for tag values (e.g., all lowercase, separated by hyphens).

**Tagging Structure (Hierarchy):**

* Flat Structure: Simple, straightforward (e.g., Owner: JohnDoe, Environment: Prod)
* Hierarchical Structure: Organized with categories (e.g., Project:MyApp/Environment:Dev, CostCenter:IT/Department:DevOps)

**Instances without Tags:**

|  |  |  |
| --- | --- | --- |
| Instance Name | Instance ID | Instance Type |
| **marvel-windows-jumboxtest** | **i-07a7a6794367ded49** | **t****3.medium** |
| **marvel-esha-windows-jumpbox-01** | **i-0378700bcf2ef68e7** | **t****3.large** |
| **marvel-rapl-amd** | **i-0c43a18a046c87984** | **t3a.large** |
| **marvel-sustain** | **i-0571933e06349edd6** | **t****2.medium** |
| **marvel-autoscaler-3** | **i-0c86e5cbdc6ef48e9** | **t****2.medium** |
| **marvel-docker-registry** | **i-0121edc6357368099** | **t****3.micro** |
| **marvel-git-perforce** | **i-0361799692abc3dc4** | **t****2.medium** |
| **marvel-esha-windows-jumpbox-03** | **i-01b006bb7ceefd989** | **t****3.large** |
| marvel-Prometheus | **i-00f4b18e0c7615802** | **t****2.micro** |
| **marvel-slurm-testing-slurmctl** | **i-02028574274244586** | **t3a.small** |
| **marvel-slurm-testing-slurm-00** | **i-0c10cab3a673568a5** | **t3a.small** |
| **marvel-slurm-testing-gw** | **i-01528621d1601b22d** | **t3a.small** |
| **marvel-slurm-testing-slurmdb** | **i-04cf6faf1252ba6a7** | **t3a.small** |

1. **Calculate energy utilization for provisioned resources and show recommendations to deployment teams**

*(Legend: R denotes Recommendation Rank)*

**Under-Provisioned:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Instance ID | Instance Type | R 1 | R 2 | R 3 |
| **i-0011eee5f9bfa37d5** | **t3.large** | **m7i-****flex.large** | **m6i.large** | **m7i.large** |
| **i-01e2bba24c61139a5** | **t3.large** | **m7i-flex.large** | **m6i.large** | **m7i.large** |
| **i-0378700bcf2ef68e7** | **t3.large** | **m7i-flex.large** | **m6i.large** | **m7i.large** |
| **i-061783c19995cf461** | **t3.large** | **m7i-flex.large** | **m6i.large** | **m7i.large** |
| **i-06b0d1885c8bfb73a** | **t2.medium** | **c7i-flex.large** | **c6i.large** | **c5.large** |
| **i-07d971daf49d26ba6** | **t3.large** | **m7i-flex.large** | **m6i.large** | **m7i.large** |
| **i-07fc1239a8432b1ff** | **t2.nano** | **t3.small** | **t3.medium** | **t3.large** |
| **i-0803db063f7902be8** | **t2.nano** | **t3.small** | **t3.medium** | **t3.large** |
| i-0a30bd8f427568294 | **t2.large** | **m7i.large** | **r7i.large** | **c7i-flex.xlarge** |
| **i-0bcac5f25c482c094** | **t3.large** | **m7i-flex.large** | **m6i.large** | **m7i.large** |
| **i-0e7f58282fba77a57** | **t3.xlarge** | **m7i-flex.xlarge** | **m6i.xlarge** | **m7i.xlarge** |

**Over-Provisioned:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Instance ID | Instance Type | R 1 | R 2 | R 3 |
| **i-07a7a6794367ded49** | **t3.xlarge** | **r7i.large** | **t3.xlarge** | **-** |
| **i-0f6c16ceb8ea482c2** | **t3.2xlarge** | **r6i.xlarge** | **r7i.xlarge** | **t3.2xlarge** |
| **i-0f97772fef03977df** | **t3.xlarge** | **r6i.large** | **r7i.large** | **t3.xlarge** |
| **i-0fda6069f43c06df1** | **t3.xlarge** | **r7i.large** | **t3.xlarge** | **-** |

1. **Identify Unused Resources**

**Unused EC2 Resources:**

|  |  |  |  |
| --- | --- | --- | --- |
| Instance Name | Instance ID | Instance Type | Unused Days |
| **marvel-GenAI-partha** | **i-0a1748bca3199a63f** | **t3.medium** | **274** |
| **marvel-LLM-test** | **i-0b43ba541b65fcd8f** | **t3.2xlarge** | **175** |
| **marvel-mddp-devsecops** | **i-0c73c29f8e5d01576** | **t3.xlarge** | **162** |
| **marvel-EEaaS-Kubernetes** | **i-0ced2e371b3425fe5** | **t3.large** | **142** |
| **marvel-TEaas-openstack-kolla** | **i-0842262e5bb3e2915** | **t3.xlarge** | **141** |
| **marvel-awx-ansible** | **i-0d5da5ba883efcf5b** | **t3.xlarge** | **127** |
| **marvel-Neureda-registry** | **i-0dc340b462af4ed74** | **t3.medium** | **125** |
| **marvel-windows-jumboxtest** | **i-07a7a6794367ded49** | **t3.medium** | **122** |
| marvel-PlatformEng-Keycloak | i-0161cf03311390911 | **t3.medium** | **121** |
| **marvel-PE-mddp-k8s-1** | **i-0bfe201057f0db5f9** | **t3.2xlarge** | **121** |
| **marvel-Prometheus** | **i-00f4b18e0c7615802** | **t2.micro** | **120** |
| **marvel-slurm-testing-slurmctl** | **i-02028574274244586** | **t3a.small** | **120** |
| **marvel-slurm-testing-slurm-00** | **i-0c10cab3a673568a5** | **t3a.small** | **120** |
| **marvel-slurm-testing-gw** | **i-01528621d1601b22d** | **t3a.small** | **120** |
| **marvel-slurm-testing-slurmdb** | **i-04cf6faf1252ba6a7** | **t3a.small** | **120** |
| **mfdm\_qual\_dd\_pg** | **i-03b6cc42f6ee8679a** | **t2.medium** | **116** |
| **tcsnxgnmfdmins5** | **i-054d01dc2082a9968** | **t3.large** | **114** |
| **tcsnxgnpemonobs01** | **i-0a30bd8f427568294** | **t2.large** | **114** |
| **tcsnxgnpemonobs02** | **i-0644a1225a61cfad0** | **t3.medium** | **114** |
| **tcsnxgnpemonobs03** | **i-0f4a538834c7f8379** | **t2.large** | **114** |
| **tcsnxgnmfdmins1** | **i-06f35320739d13110** | **t3.medium** | **113** |
| **tcsnxgnmfdmins3** | **i-0dd30488163388001** | **t3.medium** | **113** |
| **tcsnxgnmfdmins2** | **i-030fdebbe195c6d05** | **t3.medium** | **113** |

1. **Turn off workloads and node pools outside of business hours**

**Automate Shutdown/Startup**

* What It Is: Scripted automatic shutdown/startup of workloads outside business hours.

**Sustainability Benefits:**

* Reduced energy consumption
* Lower greenhouse gas emissions
* Decreased e-waste from prolonged hardware lifespan

**Identify Non-Essential Workloads**

* What It Is: Analyzing workloads to determine which can be safely turned off during non-business hours.

**Sustainability Benefits:**

* Targeted energy reduction
* Minimized unnecessary resource utilization
* Enhanced overall efficiency

**Autoscaling Configuration (Node Pools)**

* What It Is: Configuring node pools to autoscale down to 0 nodes during non-business hours.

**Sustainability Benefits:**

* Dynamic energy consumption adjustment
* Significant reduction in idle resource energy waste
* Enhanced environmental responsiveness

**Scheduled Node Pool Management**

* What It Is: Scheduling node pool shutdowns/startups using platform-specific features or tools.

**Sustainability Benefits:**

* Predictable energy savings
* Reduced operational carbon emissions
* Improved resource utilization efficiency

**Node Pool Sizing Optimization**

* What It Is: Regular review to optimize node pool sizing.

**Sustainability Benefits**:

* Continuous energy efficiency improvement
* Reduced e-waste through minimized node replacements
* Lower environmental impact

1. **Show energy efficient resource provisioning options during provisioning**

*Please refer to this* [*link*](http://marvel-teaas-lb-1490692637.us-east-1.elb.amazonaws.com:83/opa) *for a guide on how to implement this.*

1. **Implement pre-checks for common issues in CI/CD pipeline to avoid failures in different stages of pipeline**

*Please refer to this* [*link*](http://marvel-teaas-lb-1490692637.us-east-1.elb.amazonaws.com:83/prechecks) *for a guide on how to implement this.*

**Details**

1. **Development (4/24)**

Areas Implemented:

* Energy metrics for application using Intel RAPL, Kepler, Schaphandre
* Energy consumption of ML job, Model training
* Optimize source code for energy and carbon emissions using static code analysis
* Compare memory and energy utilization of docker and multi-stage docker files

Areas to be Implemented:

* Simplicity and Efficiency Trade-offs while developing algorithms
* Efficient Software Algorithms and data structures
* Efficient integration and delivery pipelines (Dev, Test, CI env)
* On demand development environments
* Minimizing unnecessary code execution
* Utilizing lazy loading
* Optimize energy consumption for Python and Java applications
* Leverage LLMs to suggest energy efficient algorithms for Java / Python applications in IDE
* Provide configurable deployment of applications with selected features to minimize resource utilization
* Calculate energy utilization at function level
* Optimize energy utilization of applications using AI/ML
* Memory optimization for applications
* Rightsizing containers and VM's based on resource utilization
* Compare and suggest open-source tools which are energy efficient
* Train models with custom rules for optimization of code
* Suggest optimized version of built-in functions which are energy efficient in IDE / static analyzer
* Code splitting - Convert code to smaller files which can be loaded on-demand
* Tree shaking: This technique helps reduce the overall application size by removing unused code from the final build, thus optimizing the web product and minimizing resource consumption
* Split large code repositories
* Remove dead code and unused data from application

1. **Network (1/2)**

Areas Implemented:

* Compare energy efficiency for synchronous (REST vs gRPC) and Asynchronous (Kafka vs RabbitMQ) messaging between microservices

Areas to be Implemented:

* Optimize data transfer (Implement local data processing, aggregation and compression techniques to avoid transfer of frequent, large amounts of data)

1. **Deployment (7/19)**

Areas Implemented:

* Tagging of resources to track usage
* Calculate energy utilization for provisioned resources and show recommendations to deployment teams
* Identify and share report on unused resources
* Turn off workloads and node pools outside of business hours
* Show energy efficient resource provisioning options during provisioning
* Implement pre-checks for common issues in CI/CD pipeline to avoid failures in different stages of pipeline
* Workload allocation on energy efficient servers, VMs

Areas to be Implemented:

* Deploy application in a region that is closest to users
* Deploy in regions that are powered by renewables or energy efficient resources
* Energy efficient workload scheduling
* CPU frequency optimization for non-critical workloads
* Alerts during resource provisioning (to avoid over provisioning) about energy consumption and energy efficient options
* Calculate and minimize energy utilization per transaction
* Implement automated decision between horizontal vs vertical scaling of applications
* Set up minimal artifacts - Reduce disk, memory and processing demands by considering the software for a given purpose
* Schedule resource intensive tasks to execute when renewable energy source is available
* Consolidate application workloads to maximize server utilization and move idle servers to low power mode
* Measure (Idle/Normal/Peak) energy consumption of resources and identify scope for optimizations (Get power consumption per CPU core information from processor type)
* Identify unused resources in K8s using KOR tool

1. **Design (0/31)**

Areas Implemented:

* No Areas Implemented

Areas to be Implemented:

* Sustainability as NFR
* Minimal Architecture (i.e. Developing minimal software for value)
* Replace long-running service with a simple Function as a Service
* Asynchronous processing and event-driven architectures
* API Design: protocol (TCP, UDP, custom wire protocols)
* API Design: data format used for request/response of your APIs: Protobuf/gRPC is better compared to JSON, XML
* API Design: Avro schemas instead of JSON for data serialization
* Reusable APIs vs P2P Integrations
* Choice of programming language: Go, Rust over Python, Java; Java 17 is better with respect to memory optimization
* Public cloud, choice of provider, and region
* Platform as a Service (PaaS) and Serverless (e.g., Function as a Service (FaaS))
* Containers and Kubernetes - Adopting energy efficient architectures such as containers or serverless
* Scheduling and batch vs. real-time - Demand Shaping
* Carbon awareness into the Kubernetes Scheduler
* Cost and Sustainability: Reducing operational costs and sustainability are aligned
* Enforce Quotas and Rate Limiting
* Reduce the Network Footprint
* Identify energy utilization of applications across different design choices
* Optimize data generation of applications
* Create reusable modules to minimize development and maintenance efforts
* Enable parallel processing using distributed computing and minimize energy consumption
* Measure KPIs on the features used by customers and remove unused features
* Energy saving mode for applications, system processes during periods of low load
* Energy budgets for applications
* Create Energy profile for application (Core Vs Non-core tasks - Logging, Monitoring, Audit, Redundancy etc...)
* Improve resilience of equipment to minimize redundancy (Ensure legacy hardware can support at least core features of software)
* Shared libraries for applications
* Server-side rendering (SSR): With SSR, a web page’s HTML is generated on the server and sent to the client, resulting in quicker initial load times and improved search engine optimization
* React frameworks: Next.js as a framework has many built-in features for energy optimization
* Progressive Web Applications (Hybrid of native and web apps) are more energy efficient
* Optimize availability and scalability needs for application

1. **Storage (0/5)**

Areas Implemented:

* No Areas Implemented

Areas to be Implemented:

* Dynamic provisioning of volumes for EC2 instance / Pod to automatically scale the storage size
* Identify and remove unused data and resources in cloud
* Implementing data retention, archival and deletion policies
* Utilize caching to store frequently used data
* Optimize log and metrics collection

1. **Quality (0/8)**

Areas Implemented:

* No Areas Implemented

Areas to be Implemented:

* Code and design review for sustainability
* Document decisions using Key Design Decisions (KDDs) or Architectural Decision Records (ADRs)
* Profiling tools and static analysis - Code profiling and optimization tools
* Upgrade Runtimes and Modules
* Change aware testing
* Test Case Optimization
* Risk Based Testing
* On-demand and scalable Test Environments

1. **Operations (0/12)**

Areas Implemented:

* No Areas Implemented

Areas to be Implemented:

* Automated sustainability maturity assessment for applications
* Observability and CarbonOps
* Automation
* Switching instances to chipsets that offer the same processing power at lower levels of energy consumption
* Sustainable DevOps practices integrate sustainability into the software delivery process
* Optimize resource allocation using ML
* Maximize utilization of resources
* Spot Instances
* Setup sustainability goals for infrastructure, development and applications and monitor them using dashboards and reports
* Reduce the cooling requirements of servers by ensuring that applications (servers) run in optimal temperature range
* Identify zombie workloads that consume resources (e.g., Application not running within container / VM)
* Dashboard for resource utilization at cluster, node, and pod level and grouped by applications in Kubernetes