A Comparative Analysis of Monolith vs Microservices Energy Consumption

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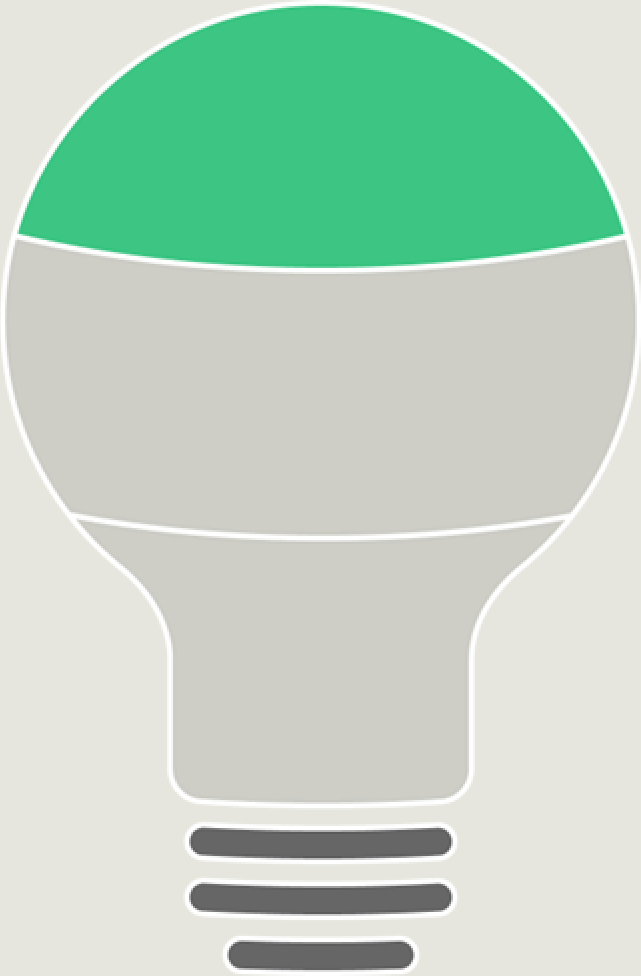
Software, at what cost?

https://www.channelnewsasia.com/today/big-read/generative-ai-environmental-impact-energy-water-5042011

Motivation

Greenhouse Gas Emissions

ICT estimated 1.8% to 3.9% of global greenhouse gas [1]



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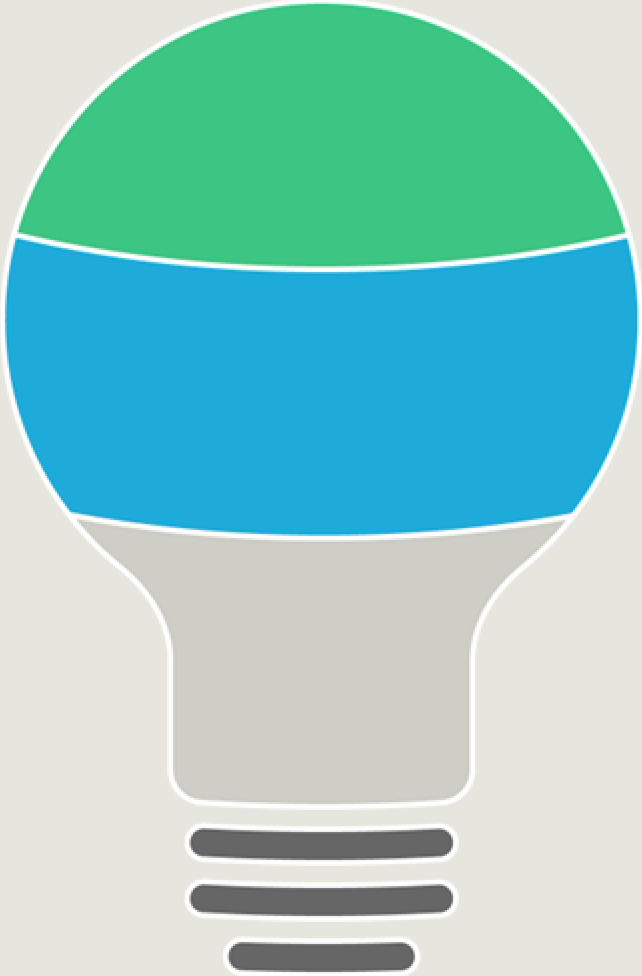

EU Regulations

The European Union's regulations on Corporate Sustainability Reporting [2]

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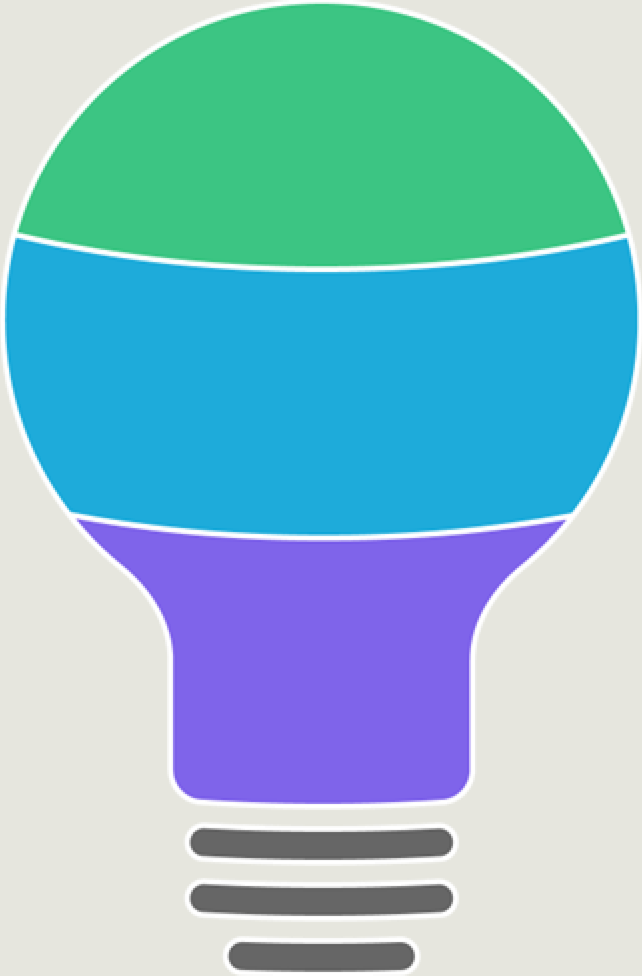
Microservices Architecture Market Value

In 2023, the global microservices architecture was valued at 3.7 billion USD [3]



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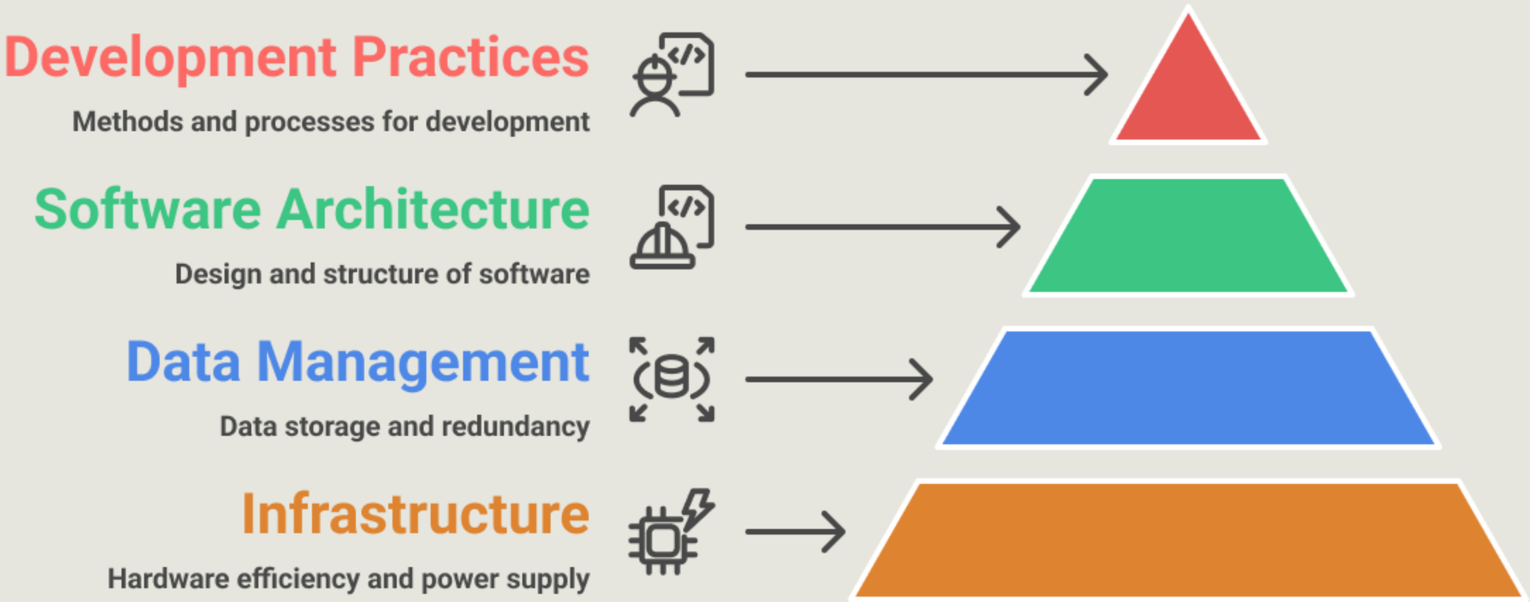
Development Practices
Methods and processes for development
Software Architecture
Design and structure of software
Data Management
Data storage and redundancy
Infrastructure
Hardware efficiency and power supply

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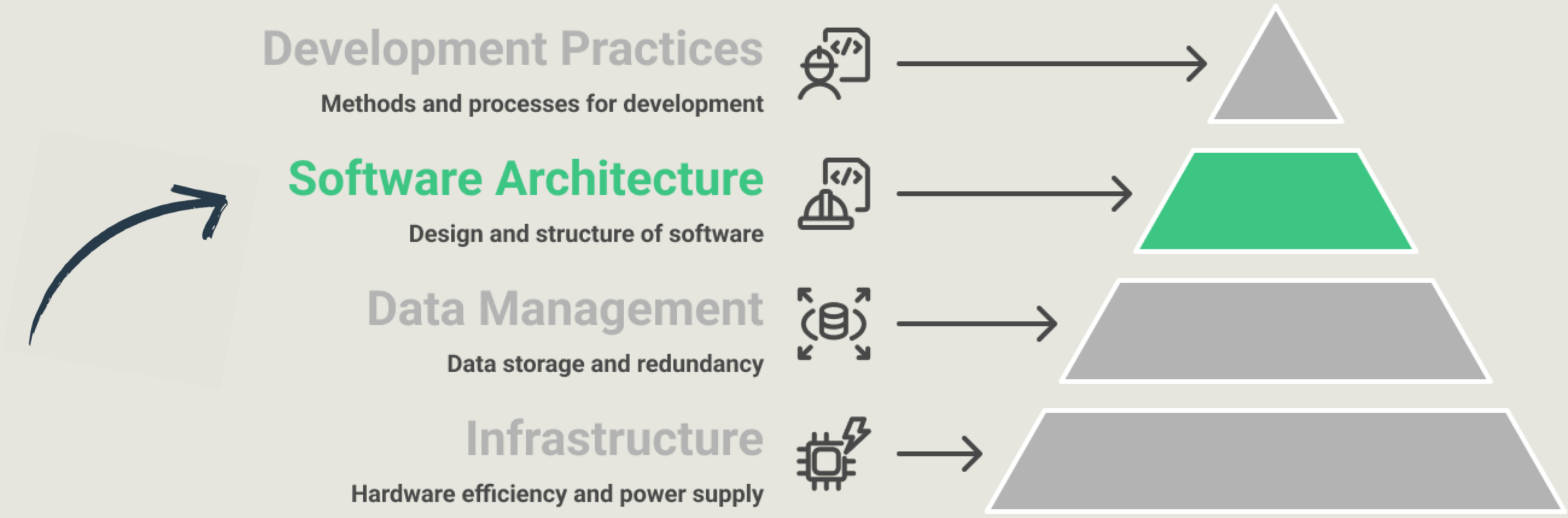
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Why Microservices?

- **Migration trend:** lots of work on *how* to migrate, but limited evidence on *energy implications*.
- **Bidirectional relevance:** migration both *to* [4,5] and *from* [6,7] microservices is common.
- **Industrial adoption:** 74% of organizations already use microservices, 23% plan to adopt [8].

Goals

- Compare **monolithic vs microservice** architectures
- Measure **energy consumption under different workloads**
- Provide **evidence to guide sustainable architectural decisions**

RQ: How does microservice architecture compare to monolithic architecture in terms of energy consumption?

The Approach: Cohort Protocol

- **Independent Variable:** architectural development model (monolith, microservices)

- **Dependent Variable:** energy consumption

- **Confounding Variable:** Other factors that may affect energy use (e.g., background processes, hardware fluctuations, network latency)

The Approach: Selection Criteria

Focus on Java

Narrowing down to Open Source Java-based projects

Sustainability Ignored

Removing sustainability as a factor

Functional Equivalence

Monolith and Microservice versions of the application available

The Approach: The Cohorts and their Selection

Cohort 1
Monolithic version of the applications

Cohort 2
Microservice version of the applications

The Approach: The Cohorts and their Selection

Case Studies
1. PetClinic
2. TicketMonster

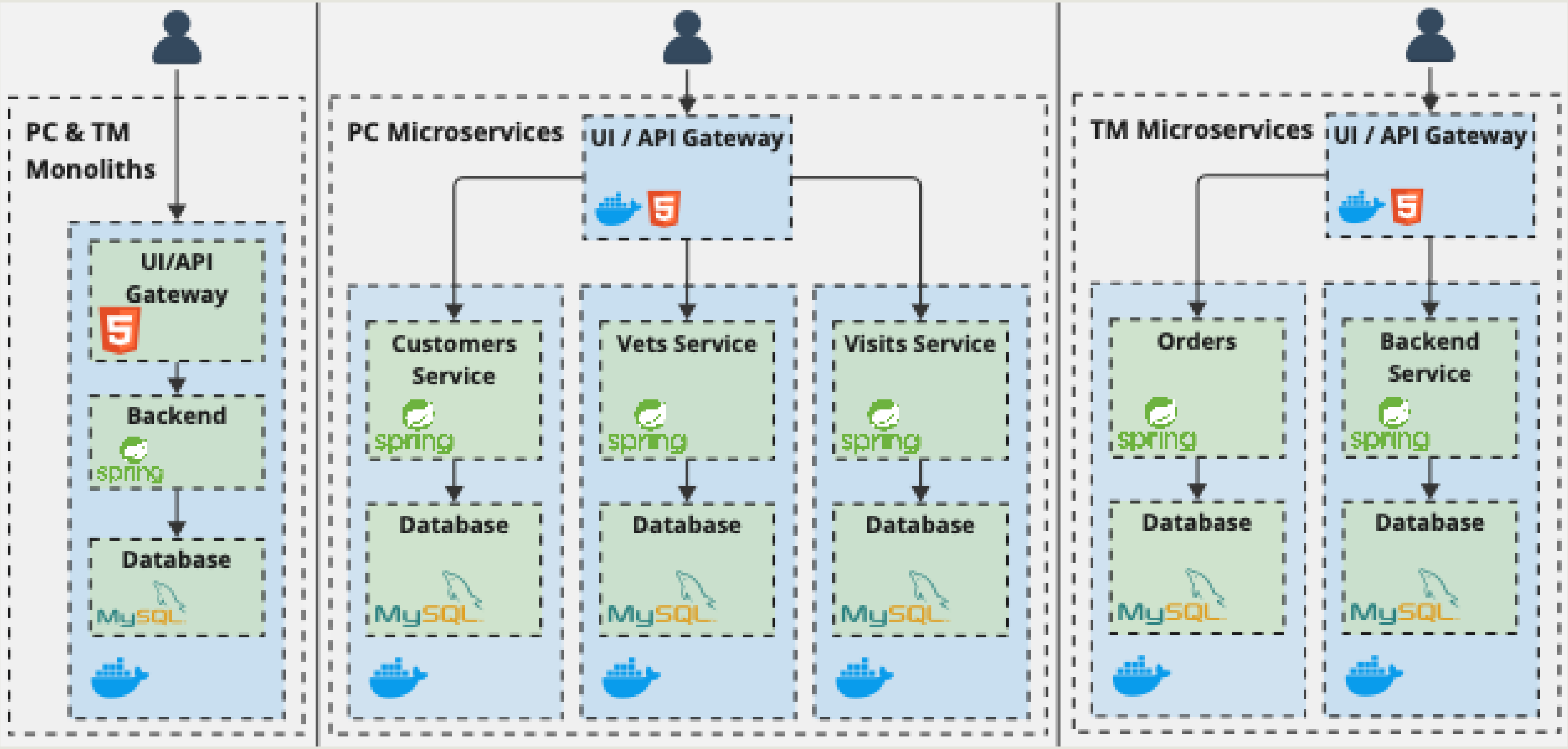
Cohort 1

Monolithic version of the applications

Cohort 2

Microservice version of the applications

Application Architectures

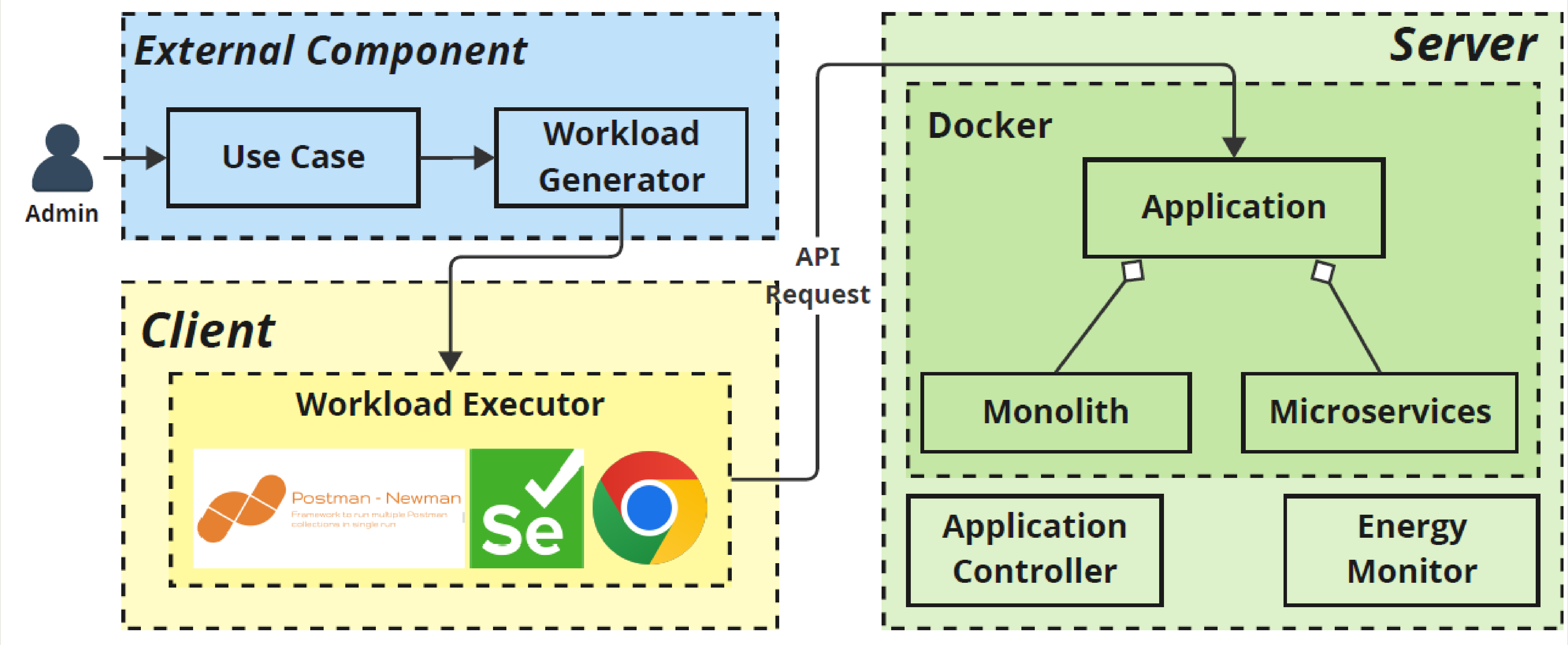


The Approach: Workloads

	Light (UC1)	Medium (UC2)	Heavy (UC3)
PC Frontend	Add owner + pet, search	Add multiple pets, update info	Create vet + appointments
TM Frontend	Browse events, buy 25 tickets (1 event)	Buy tickets (3 events)	Create venue, category, performance, event
Both Backend	10 GET requests	5 POST, DELETE requests	5 GET, POST, PUT, DELETE requests

With 50 parallel instances simulating user activity

The Experimental Setup



The Results

Table 6: Energy Comparison: Monolith vs Microservices Architectures

Application	Architecture	Use Case ID	Use Case Avg.	Overall Avg.	Mono. and Micro. Avg.
TicketMonster	Monolith	*UC1*	108.82 J	183.14 J	170.15 J
		UC2	151.52 J		
		UC3	289.08 J		
PetClinic	Monolith	*UC1*	97.42 J	157.17 J	
		UC2	150.55 J		
		UC3	223.55 J		
TicketMonster	Microservices	*UC1*	108.71 J	173.18 J	160.36 J
		UC2	142.60 J		
		UC3	268.24 J		
PetClinic	Microservices	*UC1*	97.07 J	147.54 J	
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Discussion

- Microservices may consume less energy compared to monoliths (in these case studies)
- Energy savings increase when workloads are heavier.
- Variability in energy measurements is a real issue (background processes, garbage collection).

Threats to Validity & Future Work

- **Internal Validity:** Limited to 2 apps, Java Only.
  - ➢ Replicating across more case studies
- **External Validity:** Controlled setup.
  - ➢ More realistic testing environment (scaling, latency, replication)
- **Conclusion Validity:** Results are statistically significant but constrained by sample size.
  - ➢ Increase runs & diversify workloads

Thank you!

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References

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[3] Research, S. Microservices Architecture Market — Competitive Landscape [2032]. (Straitsresearch.com,2024), https://straitsresearch.com/report/microservices-architecture-market

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[5] Taibi, D., Lenarduzzi, V., and Pahl, C. (2017). Processes, motivations, and issues for migrating to microservices architectures: An empirical investigation. IEEE Cloud Computing, 4(5), 22-32.

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[8] Gartner, Inc. Microservices Architecture: Have Engineering Organizations Found Success?, Gartner Peer Community, 2023. Available: https://tinyurl.com/bdetfjwz