Towards Modeling and Analysis of Power Consumption of Self-Adaptive Software Systems in Palladio

Symposium on Software Performance 2014

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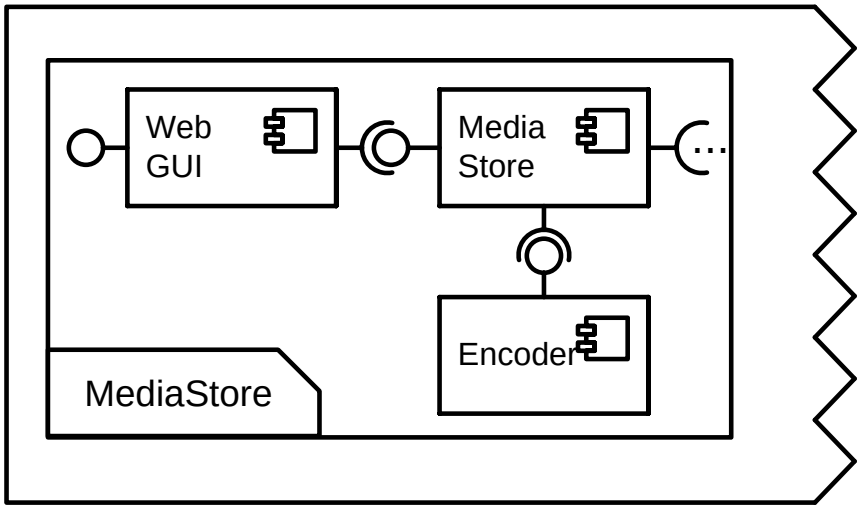
FZI FORSCHUNGSZENTRUM INFORMATIK

cactos

Motivation



Performance

Reliability

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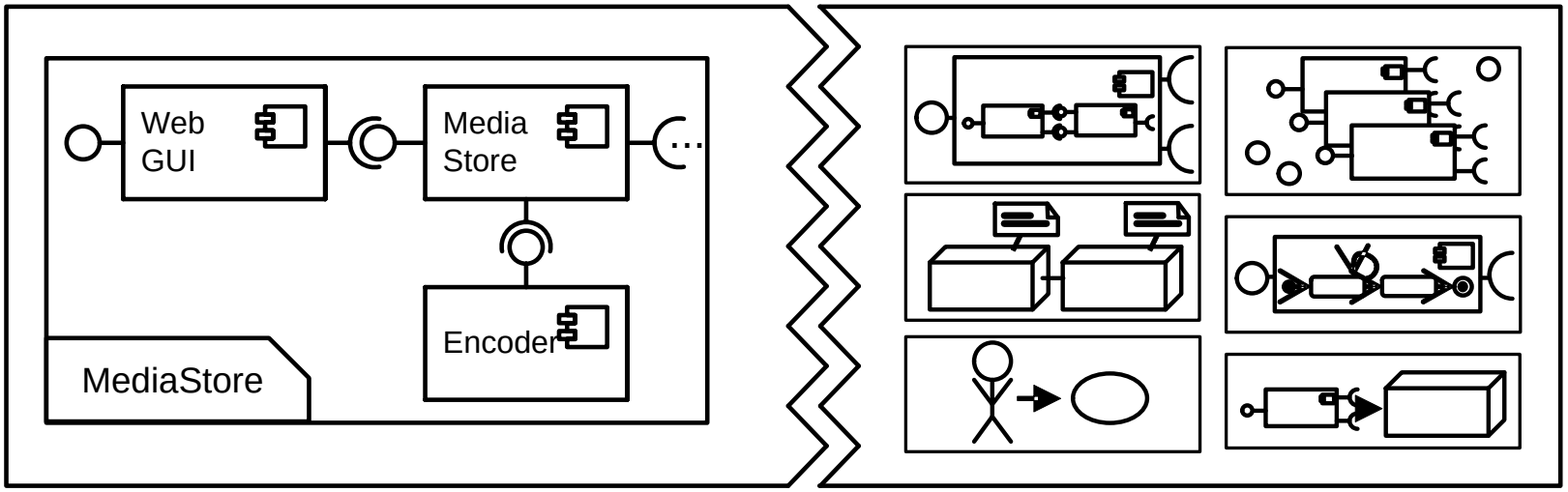
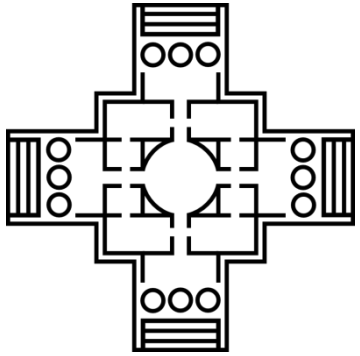
Motivation



Performance

Reliability



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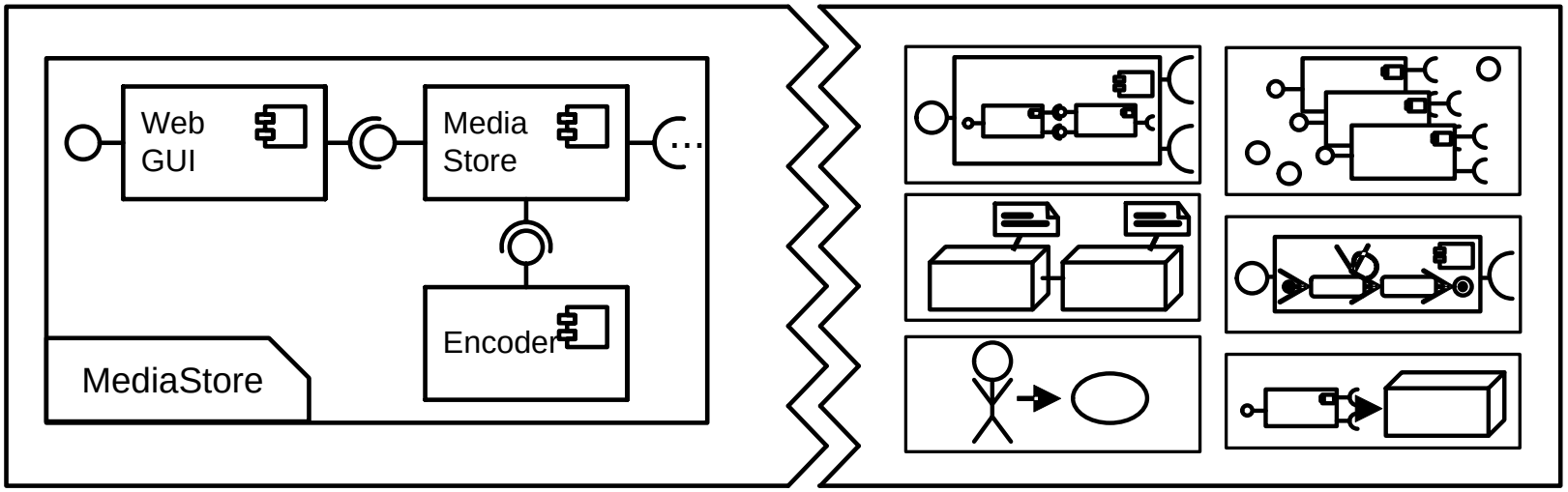

Performance

Reliability

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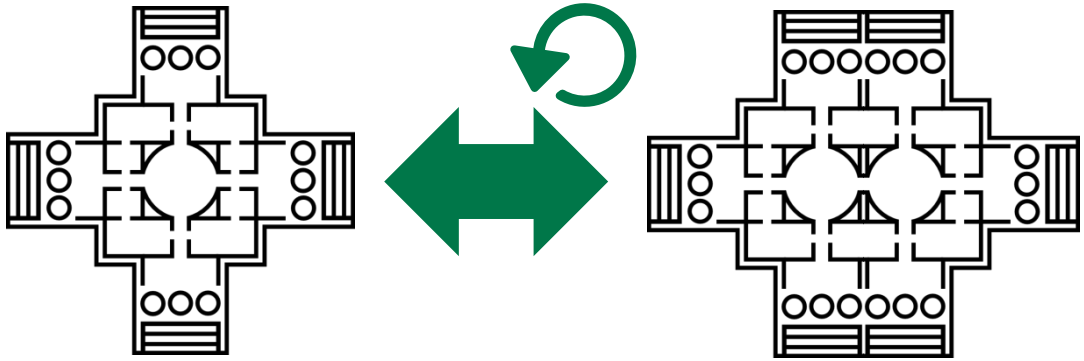
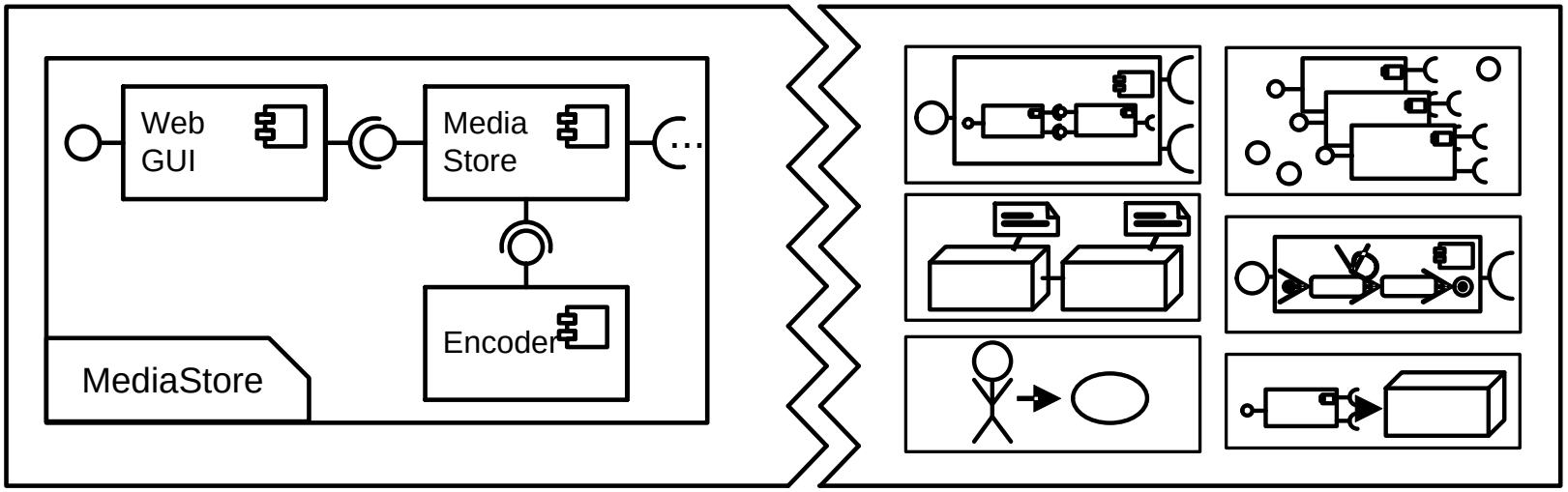
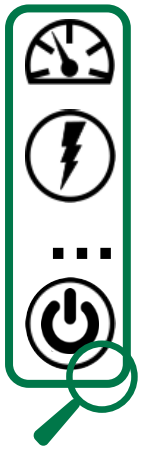


Becker et al. **[BBM13,BLB13]**

Motivation





Performance

Reliability

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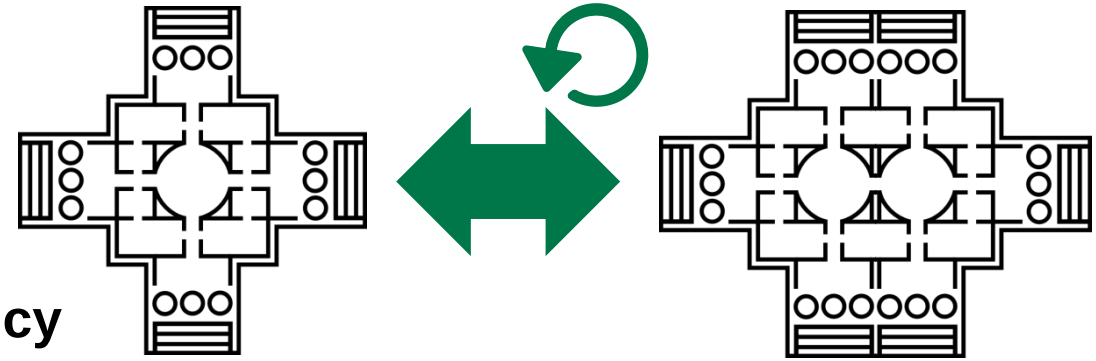
Energy Efficiency

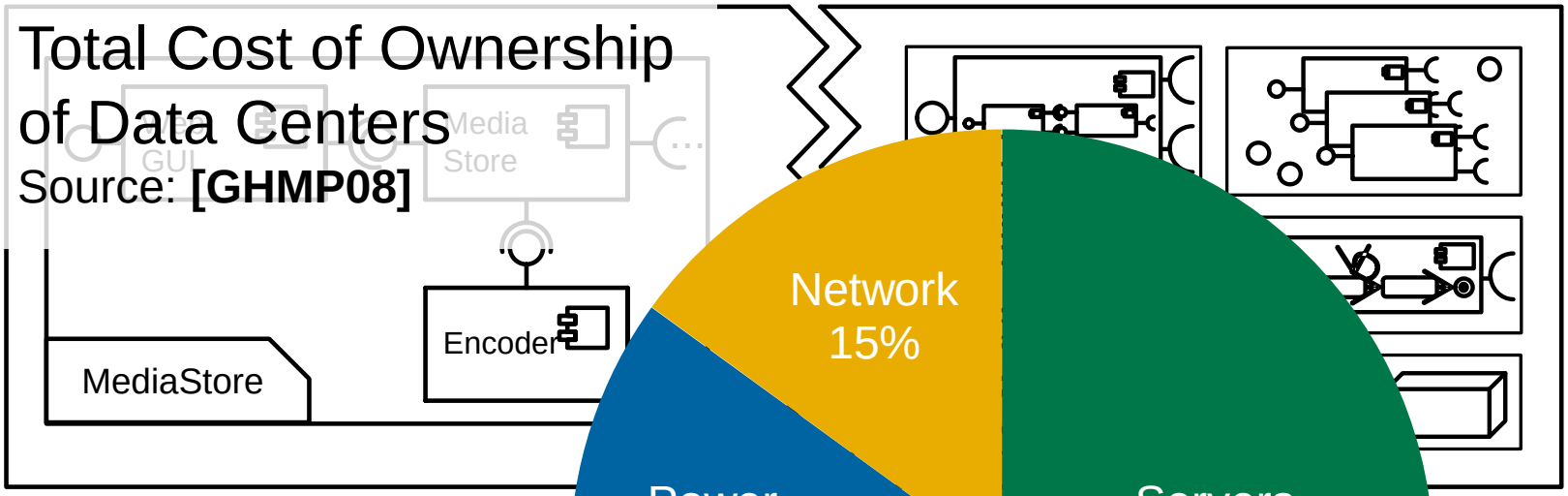


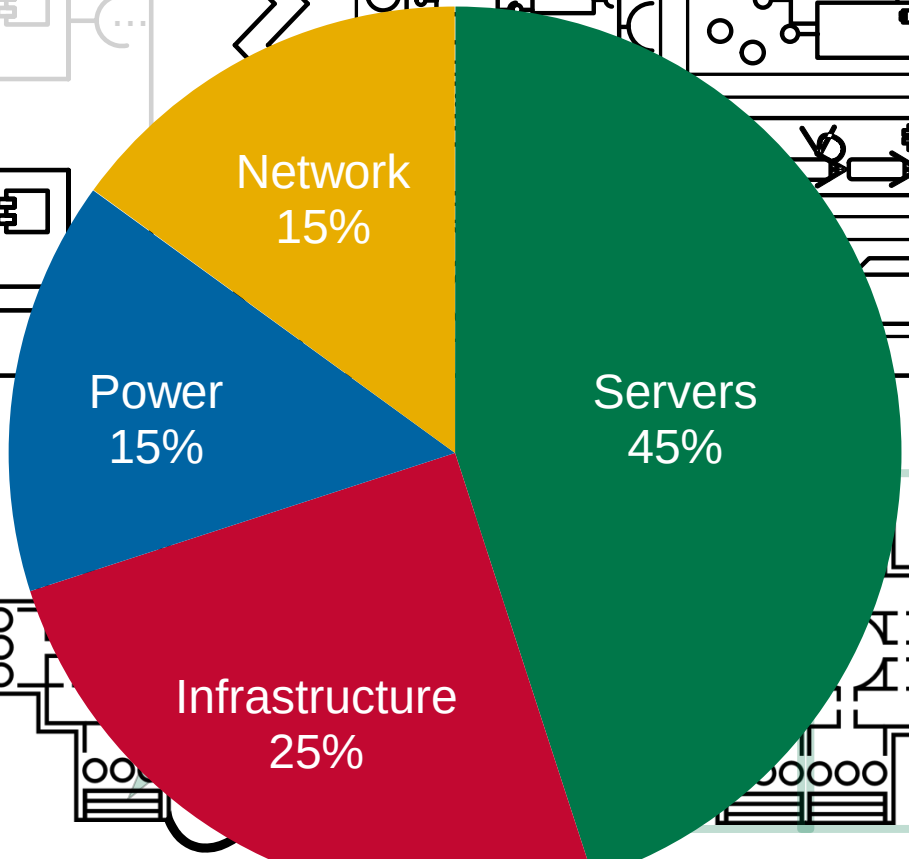
Becker et al. **[BBM13,BLB13]**

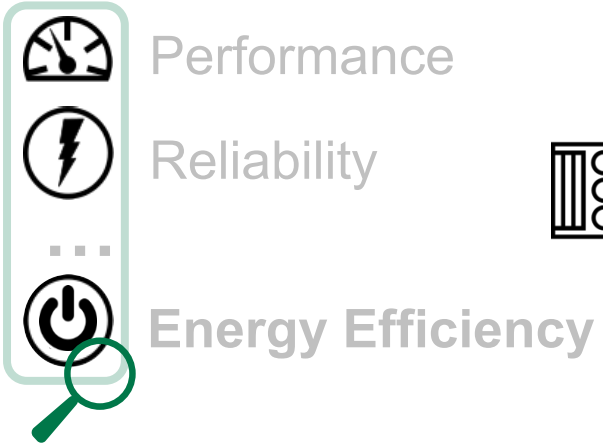
Motivation

Total Cost of Ownership of Data Centers

Source: **[GHMP08]**







Performance

Reliability

...

Energy Efficiency

Becker et al. **[BBM13,BLB13]**

Towards? – Results and Roadmap

- Extending PCM with power consumption characteristics ✓
- Power consumption analysis ✓
- Validation for static software systems 
- Support for power-conscious self-adaptations 

Related Work

Architecture-level energy consumption analysis

- Seo et al. **[SEMM08]**
- Meedenyia **[MBAG10]**
- Brunnert et al. **[BWK14]**

Mobile software systems

- Willnecker et al. **[WBK14]**

Energy-conscious self-adaptive software systems

- Götz et al. **[GWCA12,GWR13]**
- Calheiros et al. **[CRB+11]**

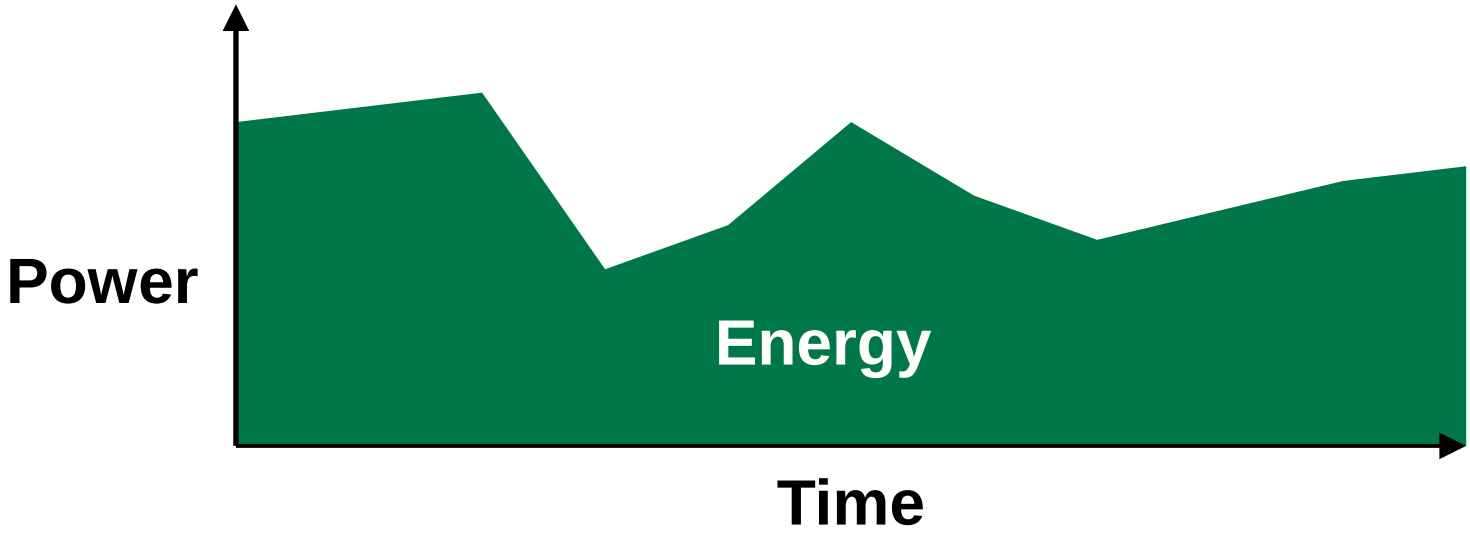
Foundations – Power and Energy Consumption

Power Consumption

- Rate at which system consumes energy

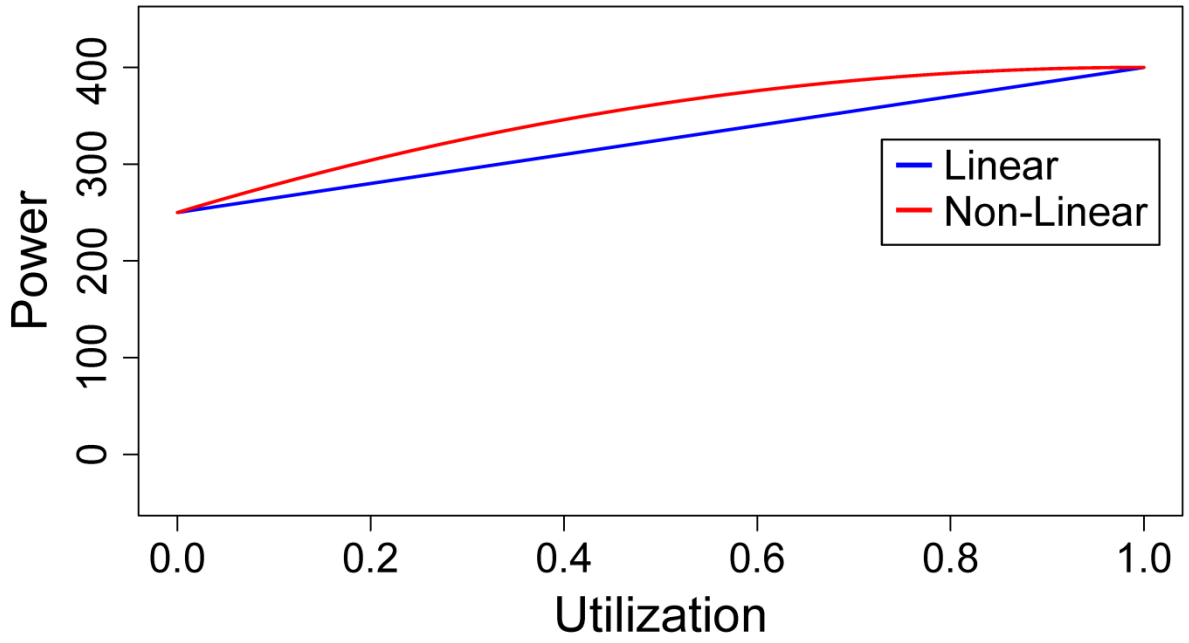
Energy Consumption

- Power consumption over time



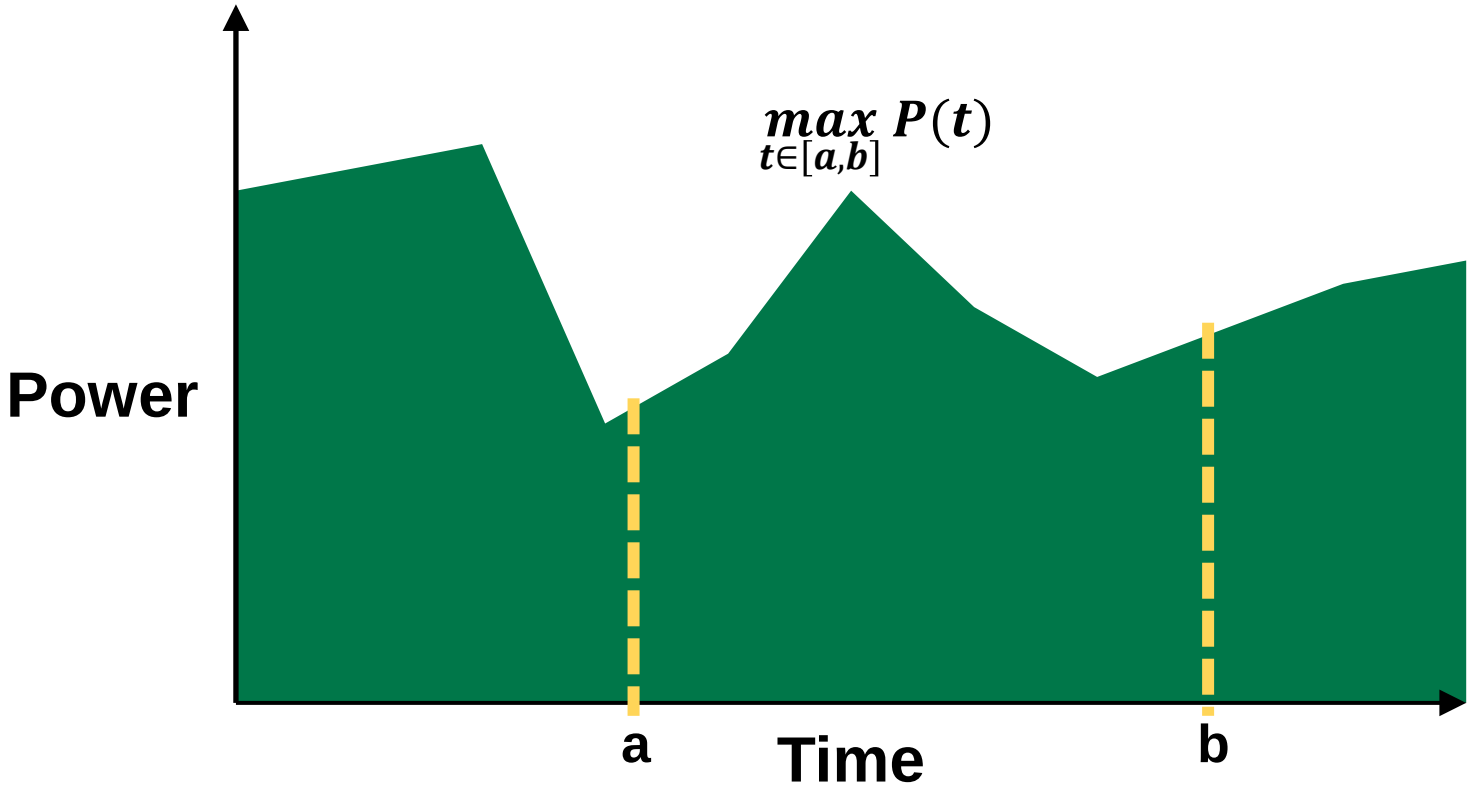
Foundations – Power Models

- **Purpose:** Estimate power consumption based on system metrics, e.g. CPU utilization
- Regression-based correlation of system metrics and power consumption



Foundations – Peak Power

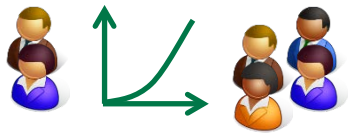
- Maximum power consumption in an interval: $\max_{t \in [a,b]} P(t)$

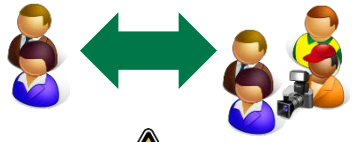


Foundations – Why Peak Power matters

- Power distribution infrastructure needs to be capable of handling peak load
- Higher supported peak power draw → Higher infrastructure cost: $10 to $20 per available Watt of peak power **[FWB07]**
- Stronger overprovisioning → Higher risk of blackout/HW failure

- Degree of overprovisioning depends on
  - Usage profile
  - Workload mix
  - Accepted risk





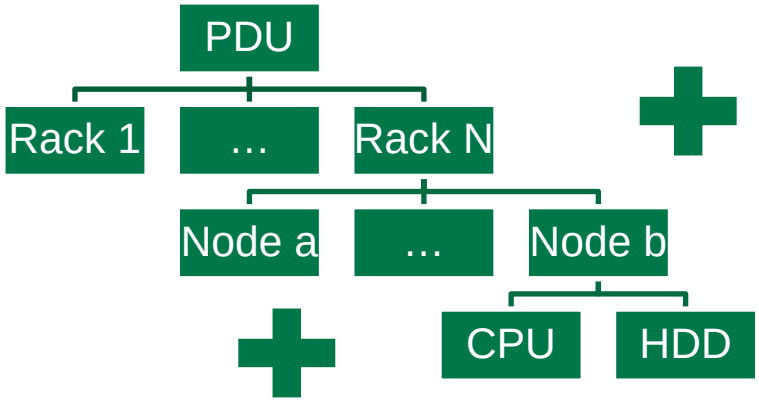
Foundations – Why Peak Power matters

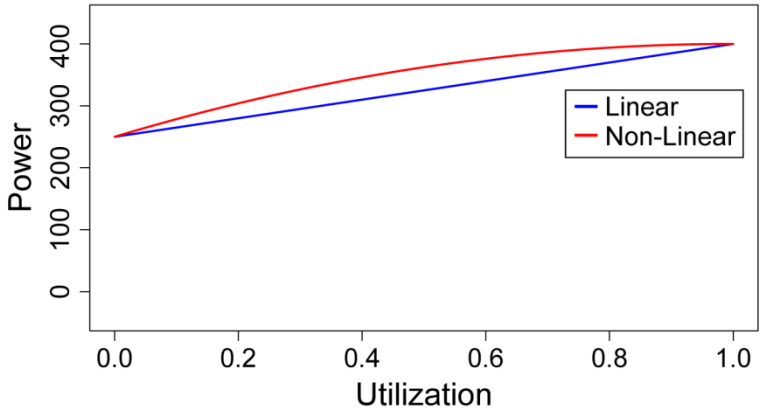
Energy cost depend upon

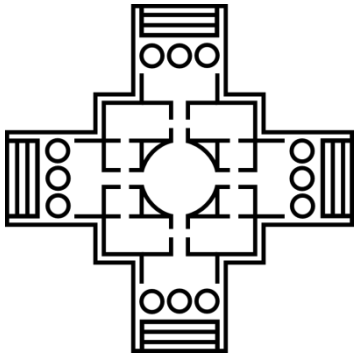
- Energy consumption
- Peak power consumption **[ZWW12]**

Analyzing Power Consumption with Palladio

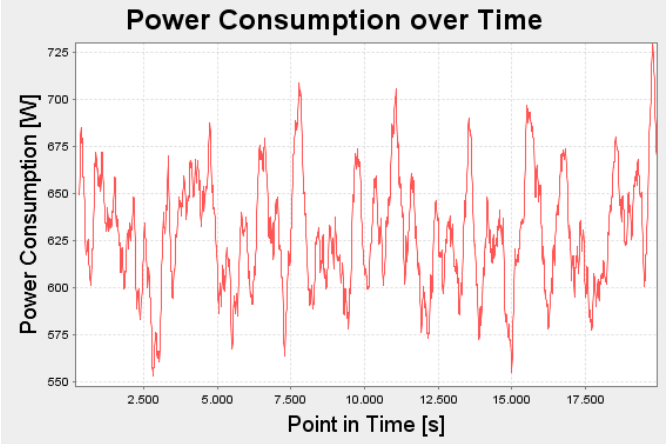
- Extend Palladio by definition of power consumption characteristics
- **Purpose:** Power consumption analysis





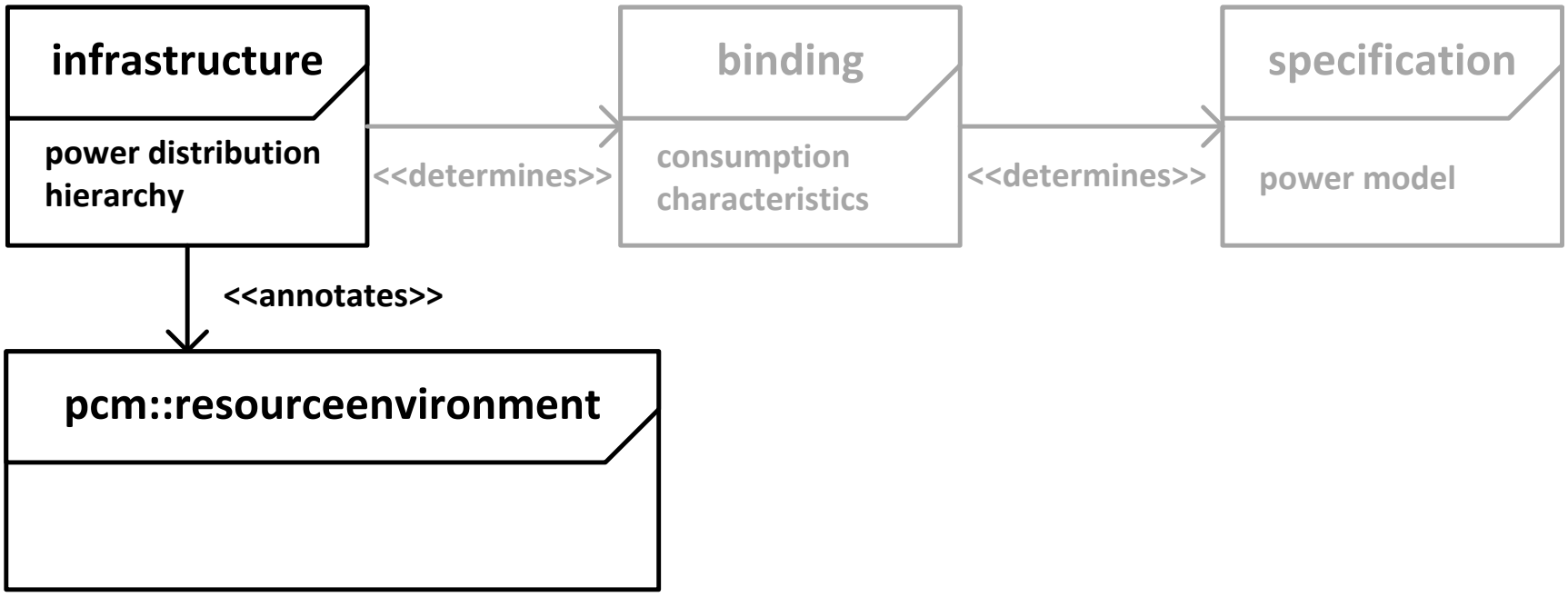


Analyze



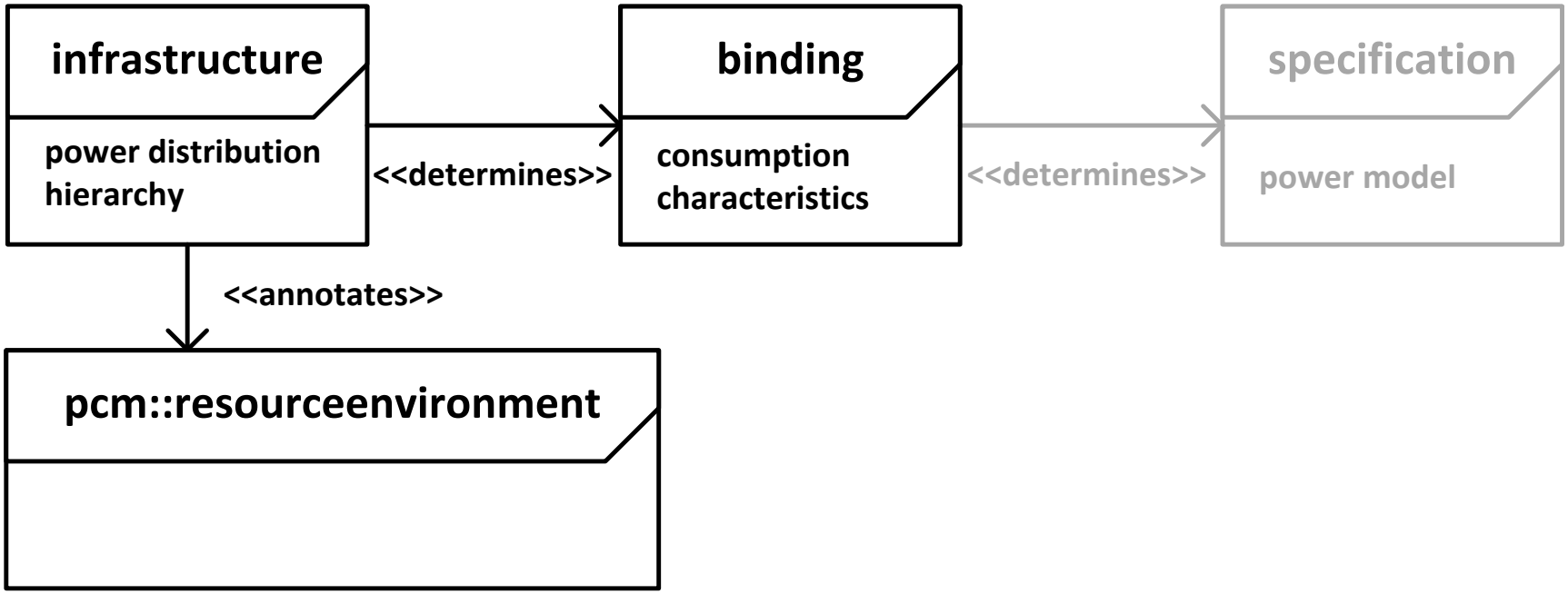
Power Consumption Model – Infrastructure

- Power distribution hierarchy
- Consumption characteristics per resource



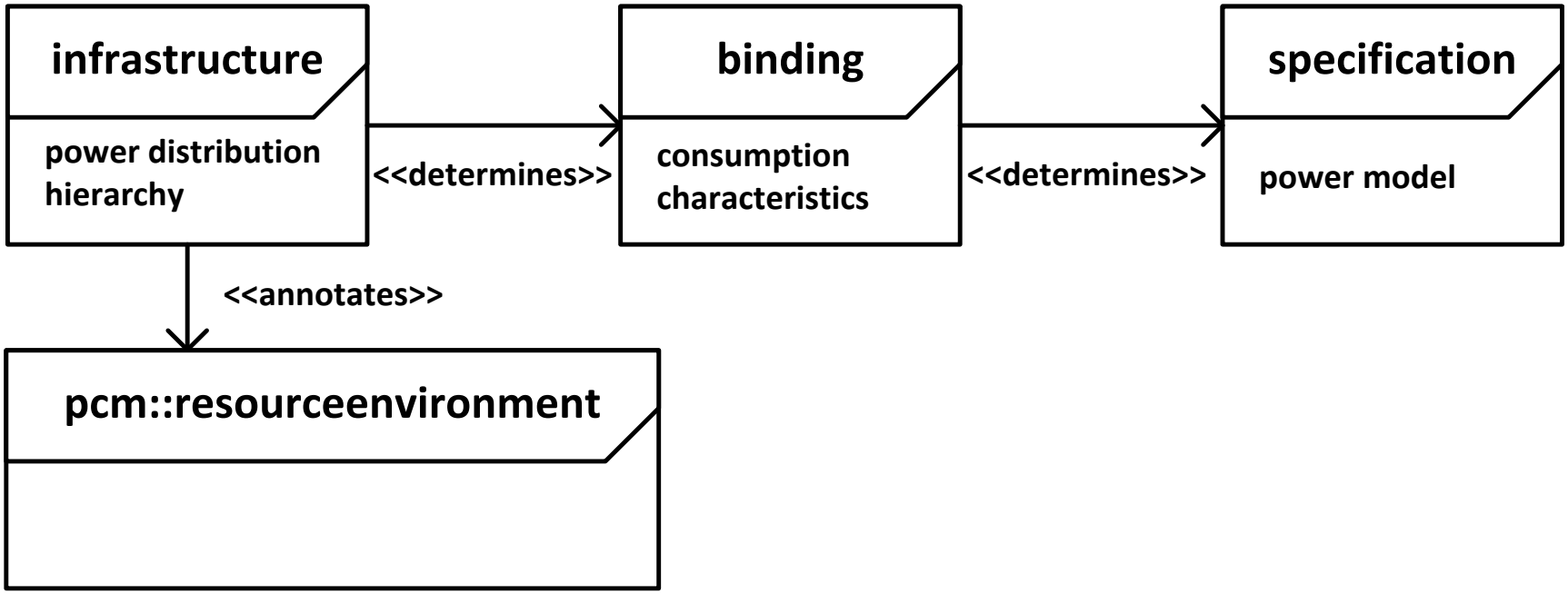
Power Consumption Model – Binding

- Consumption properties of *resource types*
- Examples:
  - Power consumption of Xeon E5-4650 under full/idle load
  - Conversion loss of power distribution unit under full/idle load



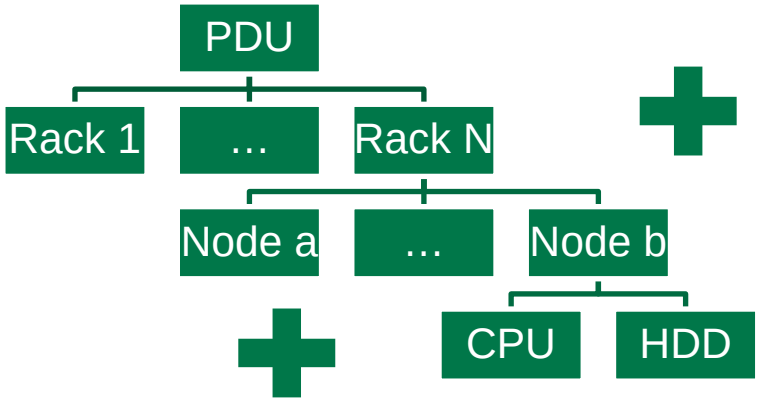
Power Consumption Model – Specification

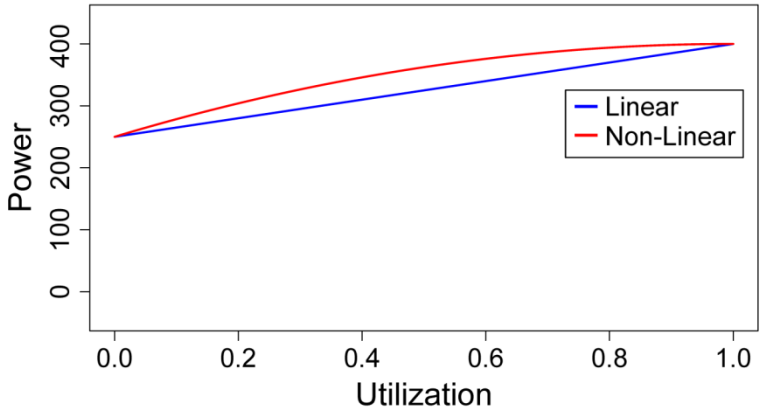
- Power models of resources and distribution infrastructure
- Examples:
  - Linear CPU-based
  - Complex regression model for CPU and HDD

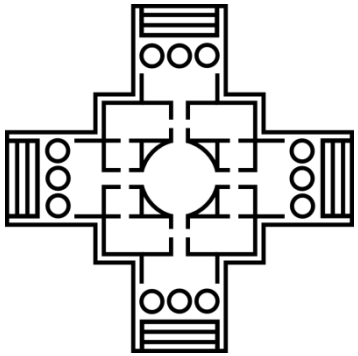


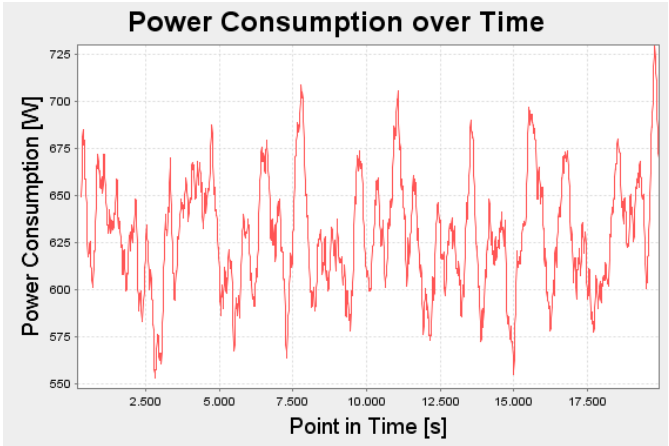
Power Consumption Analyzer (PCA)

- Calculate power consumption per entity



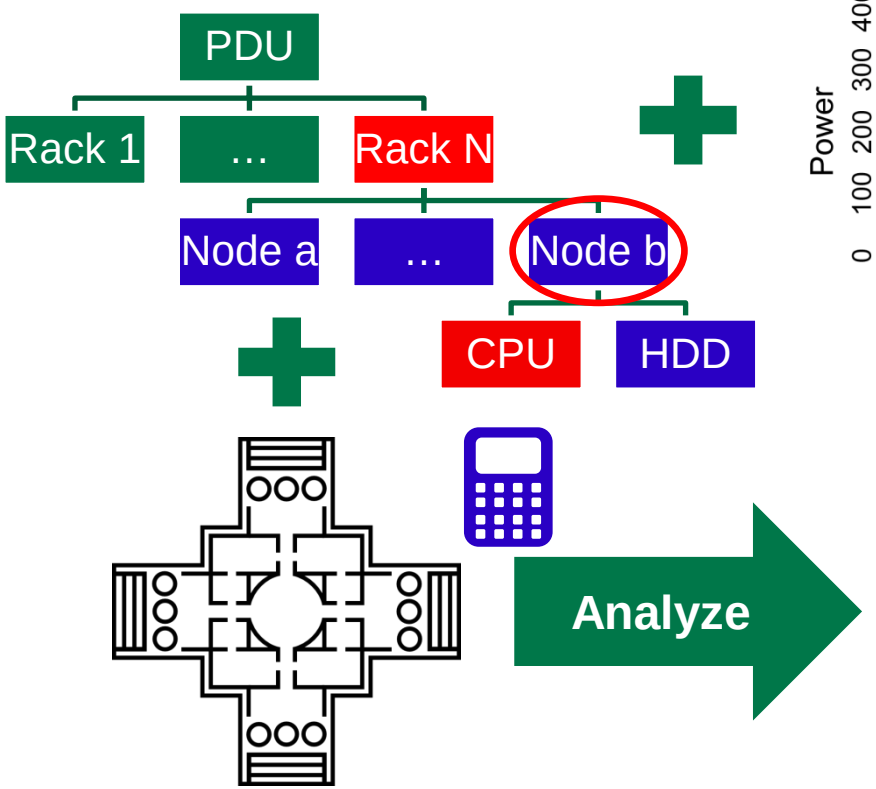


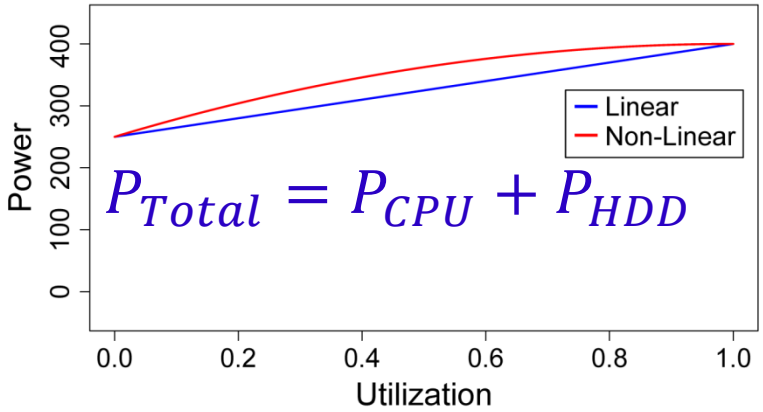


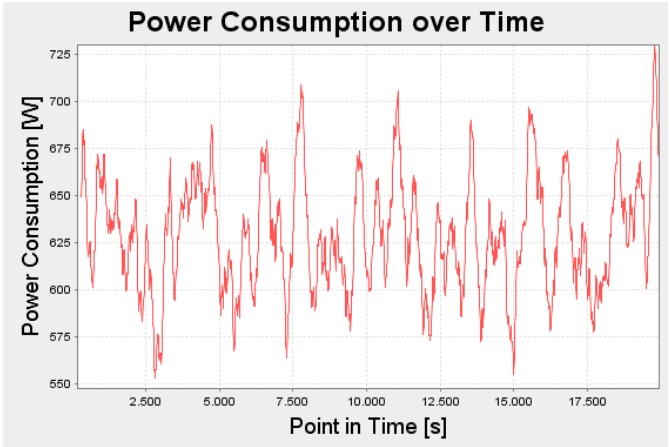


Power Consumption Analyzer (PCA)

- Calculate power consumption per entity
- Dedicated calculator implementation per regression model







PCA – Use Cases

Post-simulation analysis

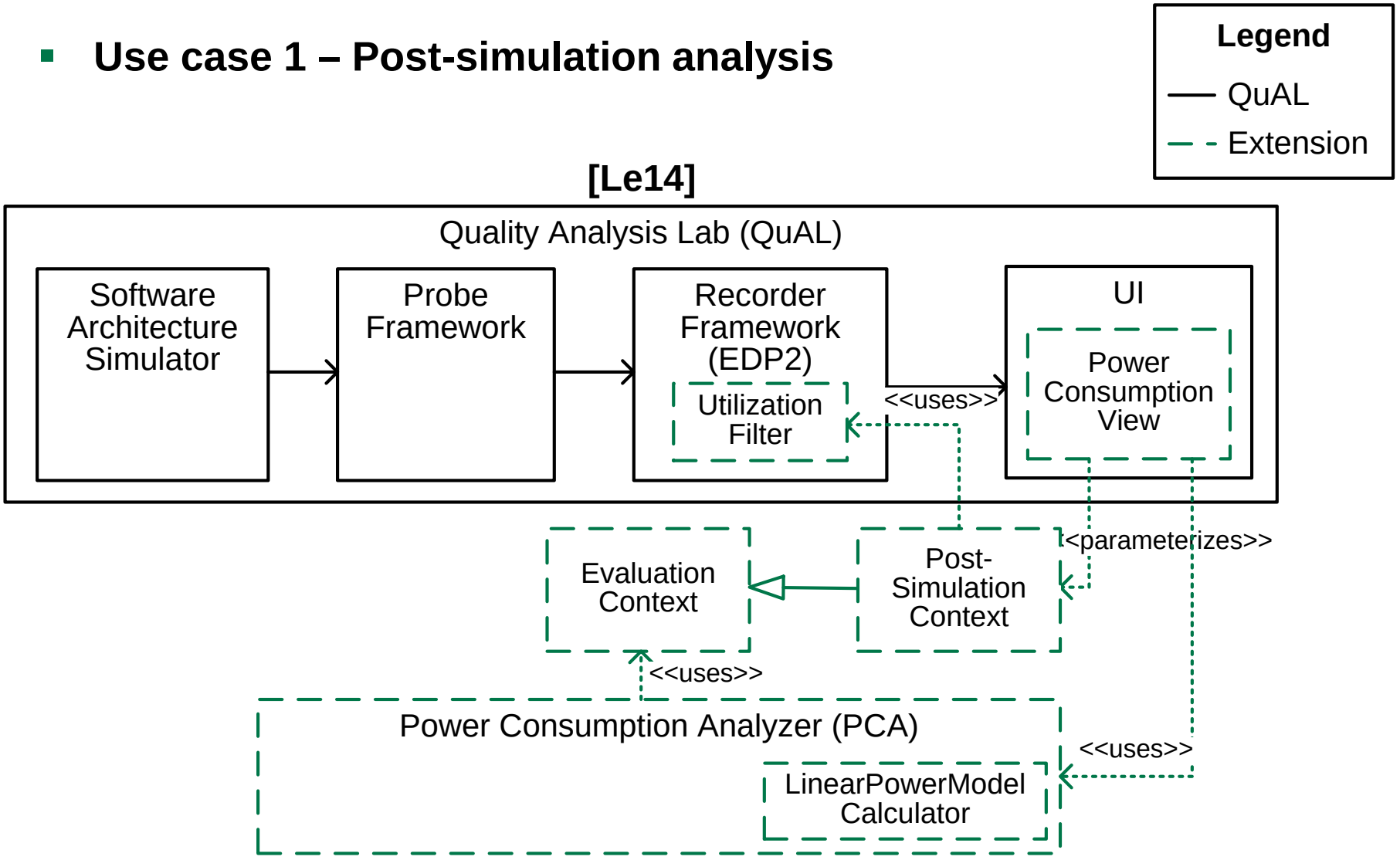
- Analyze power consumption of a software system
- **Challenges:**
  - Separate consumption analysis and simulation logic
  - Aggregation of results over distribution hierarchy and time
  - Enable reconfigurability and extensibility of analysis

Intra-simulation analysis

- Evaluate the impact of power-conscious self-adaptation tactics on multiple quality characteristics
- **Challenge:** Integrate consumption analysis with self-adaptation process

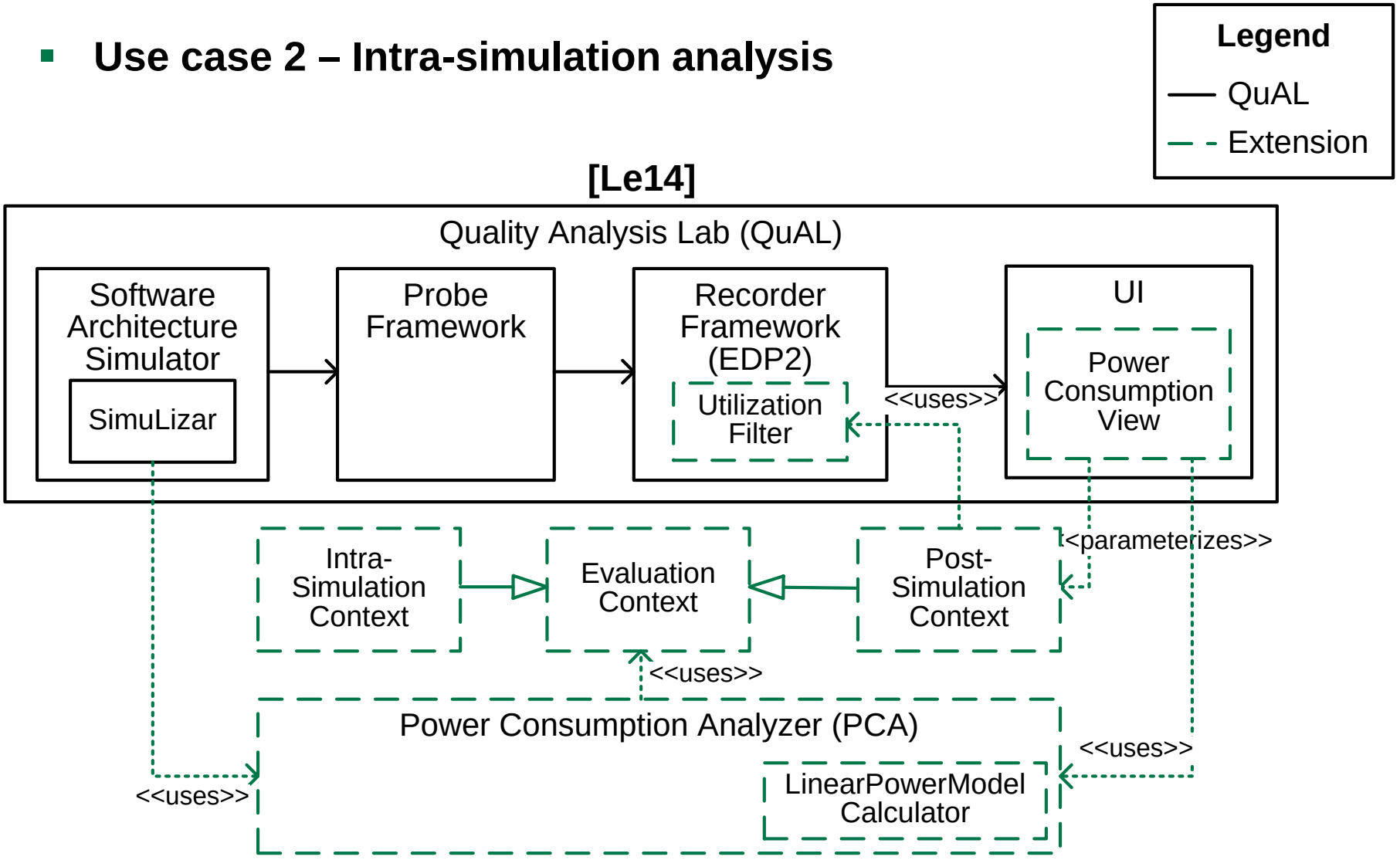
Integrating the PCA with Palladio

- **Use case 1 – Post-simulation analysis**

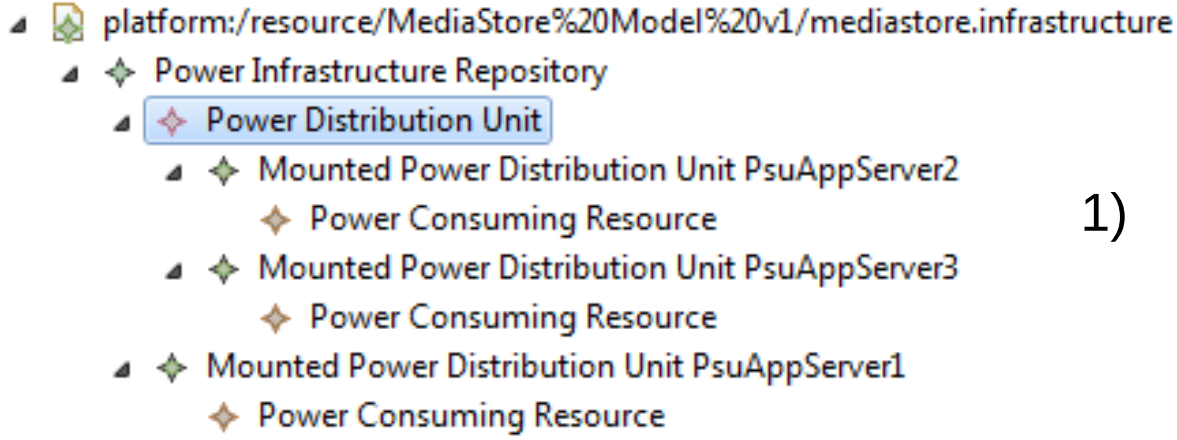


Integrating the PCA with Palladio

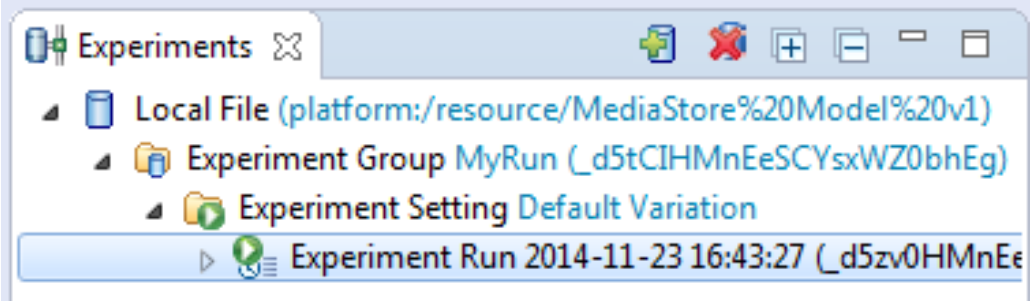
- **Use case 2 – Intra-simulation analysis**



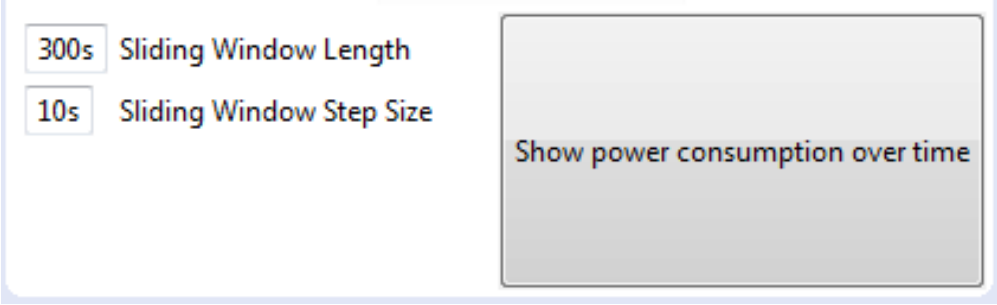
Palladio Workbench Integration



1) Select infrastructure element

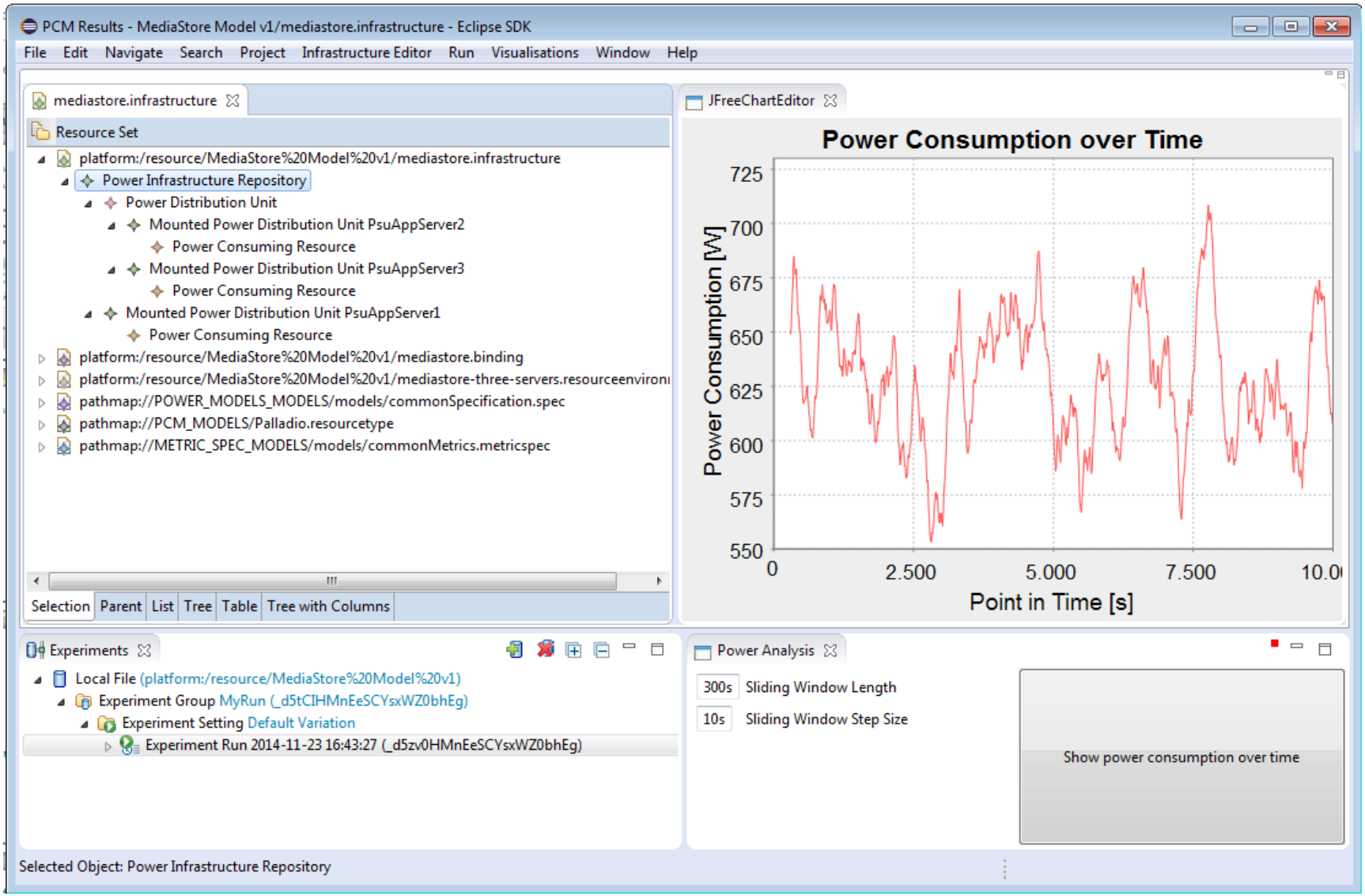


2) Select experiment run in EDP2



3) Start analysis

Palladio Workbench Integration



- Extending PCM with power consumption characteristics ✓
- Power consumption analysis ✓
- Validation for static software systems
- Support for power-conscious self-adaptations

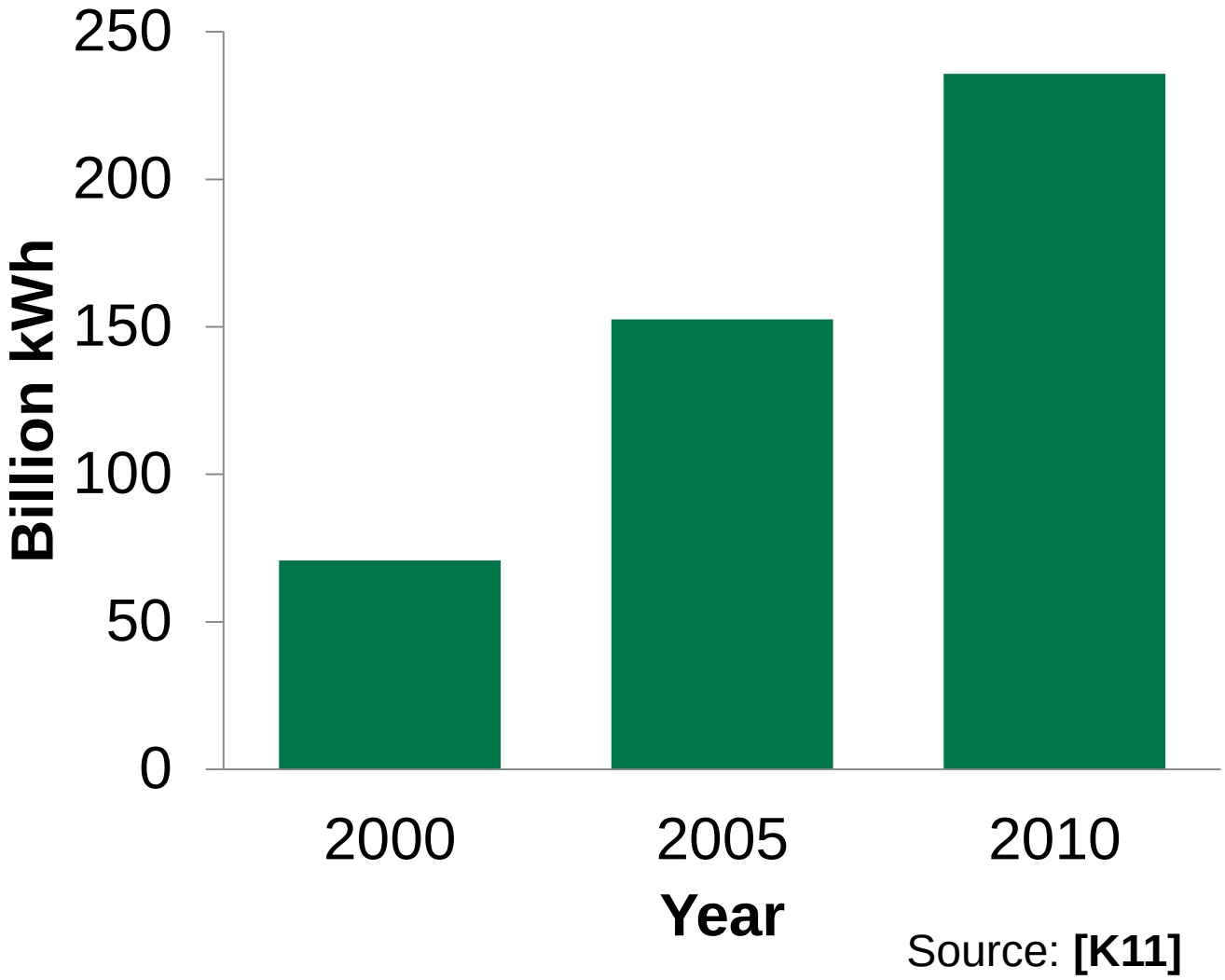
Thank you!

Questions?

Ideas?

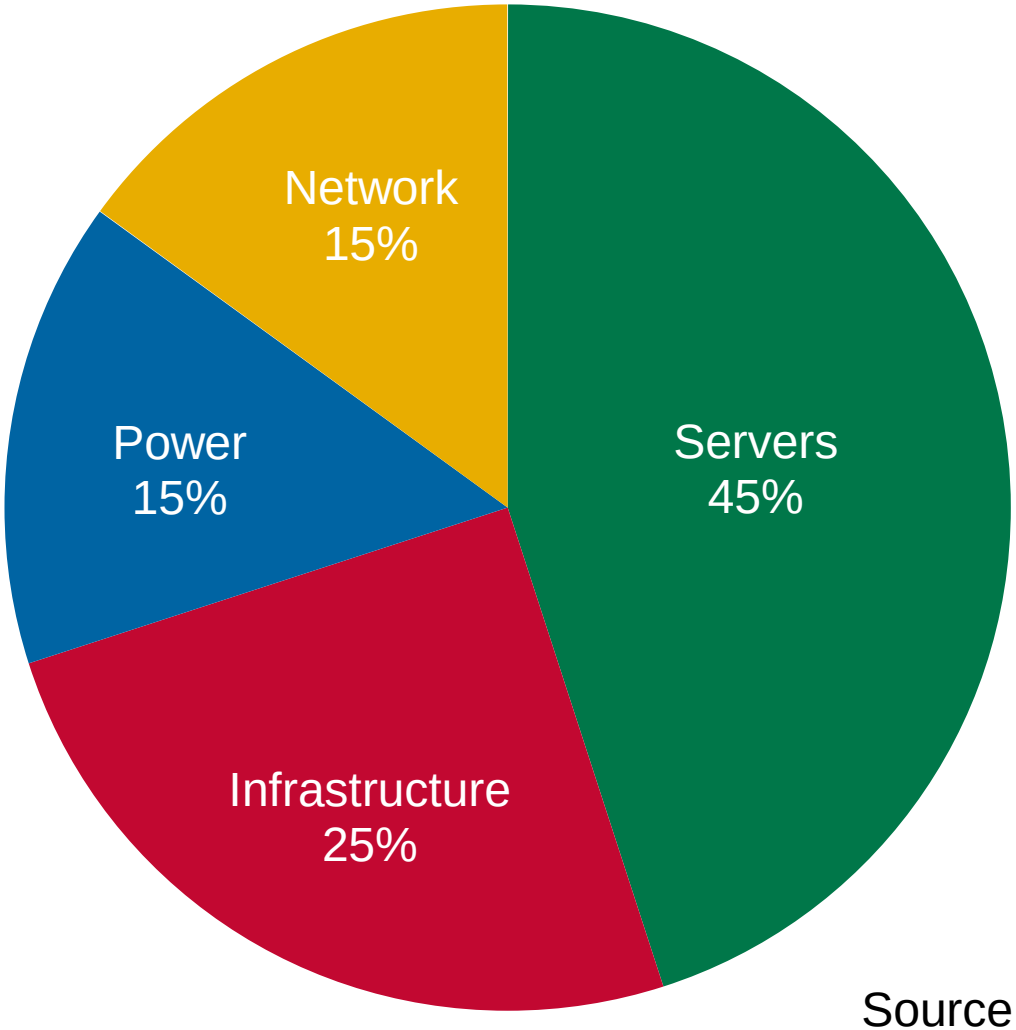
Suggestions?

Energy Consumption of Data Centers



Source: **[K11]**

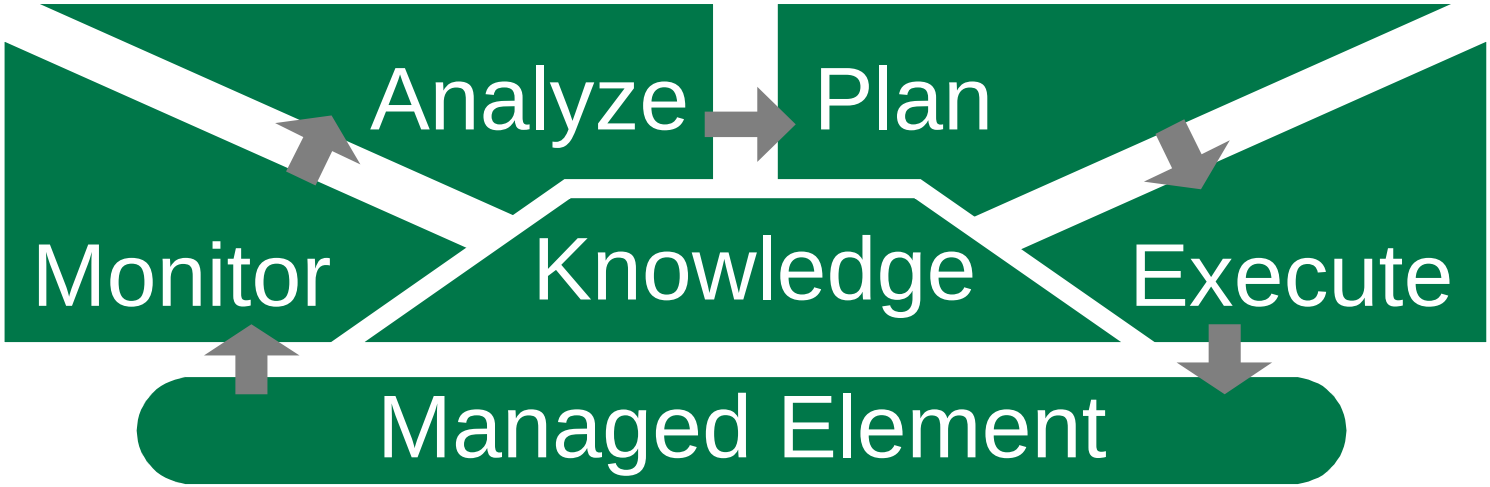
Total Cost of Ownership of Data Centers



Source: **[GHMP08]**

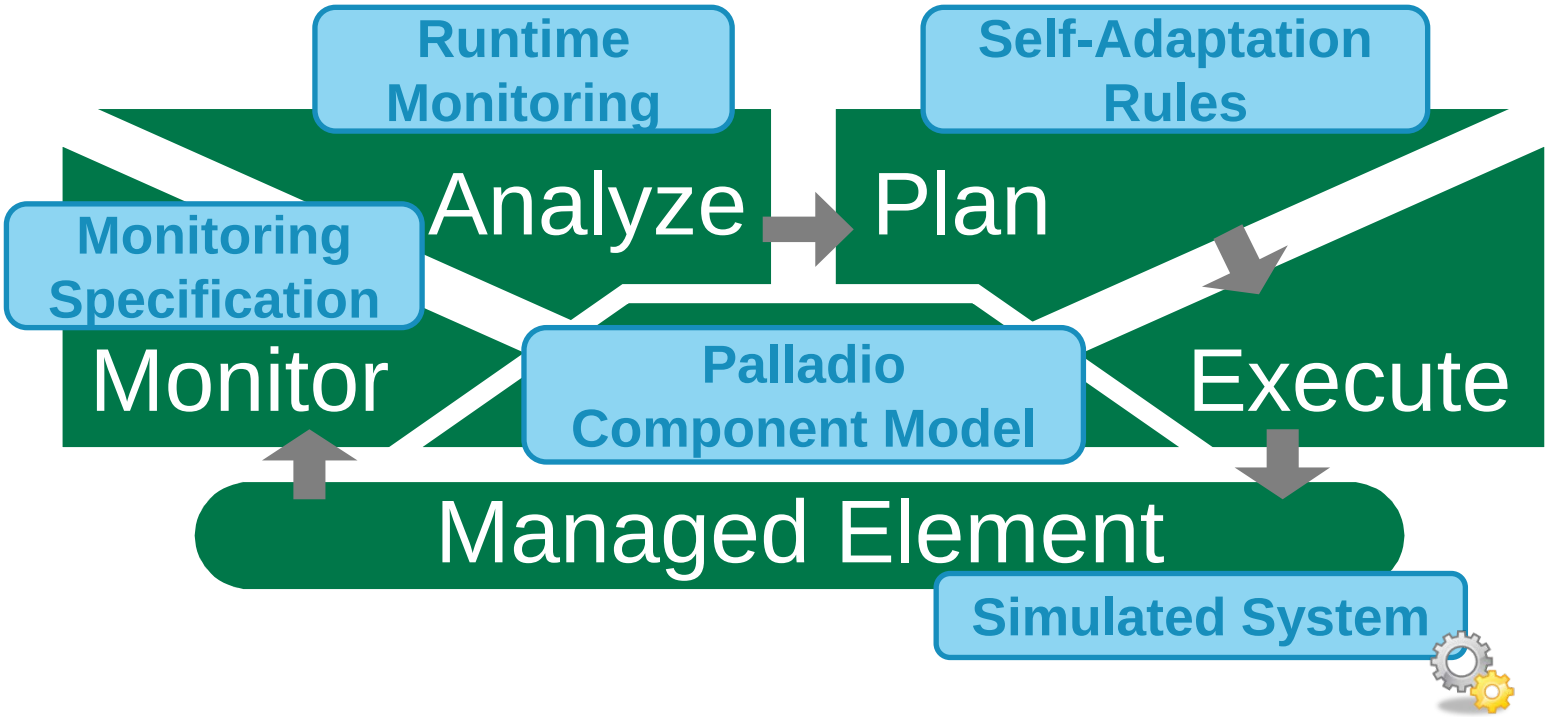
Foundations – Self-Adaptive Systems

- Self-adaptive systems modify their structure and functionality based on changes in the environment
- MAPE-K loop **[KC03]**



Foundations – Self-Adaptive Software Systems

- **Becker et al. [BBM13,BLB13]:** Design and analysis of self-adaptive software systems



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- Nichole, Gears Clipart, retrieved from: http://www.clker.com/clipart-gears.html (24/11/2014)