



University  
of  
St Andrews

# A FLEXIBLE ENERGY MONITOR

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# Introduction

- PhD student
  - ▣ **Yi Yu** (full name)
  - ▣ @ University of St Andrews
  - ▣ Started ~6 months ago
  - ▣ Supervised by **Prof. Saleem Bhatti**
- Research interests
  - ▣ Energy monitoring & energy efficiency in large-scale ICT systems
  - ▣ Making system management policies energy-aware



# Energy and the Cost

- The ICT industries are responsible for 2% of the global carbon emissions in 2008, 3% by 2020. <sup>1</sup>
  - ▣ Similar to what the aviation industries produce!
- Governmental actions:
  - ▣ Raise electricity prices
  - ▣ Add Carbon TAX
- Operational Expenditure (OPEX) to outweigh Capital Expenditure (CAPEX) by 2015. <sup>2</sup>

1 *Parliamentary Office of Science and Technology, "Postnote Number 319: ICT AND CO2 EMISSIONS."* [www.parliament.uk/documents/post/postpn319.pdf](http://www.parliament.uk/documents/post/postpn319.pdf), December 2008

2 *Microsoft, "Microsoft Environment - The Green Grid Consortium."* [http://www.microsoft.com/environment/our\\_commitment/articles/green\\_grid.aspx](http://www.microsoft.com/environment/our_commitment/articles/green_grid.aspx), 2009



# Research Questions

- ✓ How can we gather energy information on a system-wide basis, at scale, including heterogeneous devices in the ICT infrastructure?
- What exact correlation do workload and workstation energy consumption have?
- What metrics and KPIs are suitable for use in system management policies and Service Layer Agreements (SLAs)?
- What effects are there on system operations and performance when energy information is included into system management policies?



# Motivation

- Psychological studies have shown that providing accurate and timely energy usage feedbacks to users, does change their behaviours, and promote energy saving habits. <sup>1,2</sup>
- Data centres are large and complex systems. Simply assembling a collection of improved equipments will not necessarily result in the most energy efficient whole. <sup>3</sup>
- Today, no generic energy measurement infrastructure exists that can provide detailed feedbacks of system-wide energy usage.



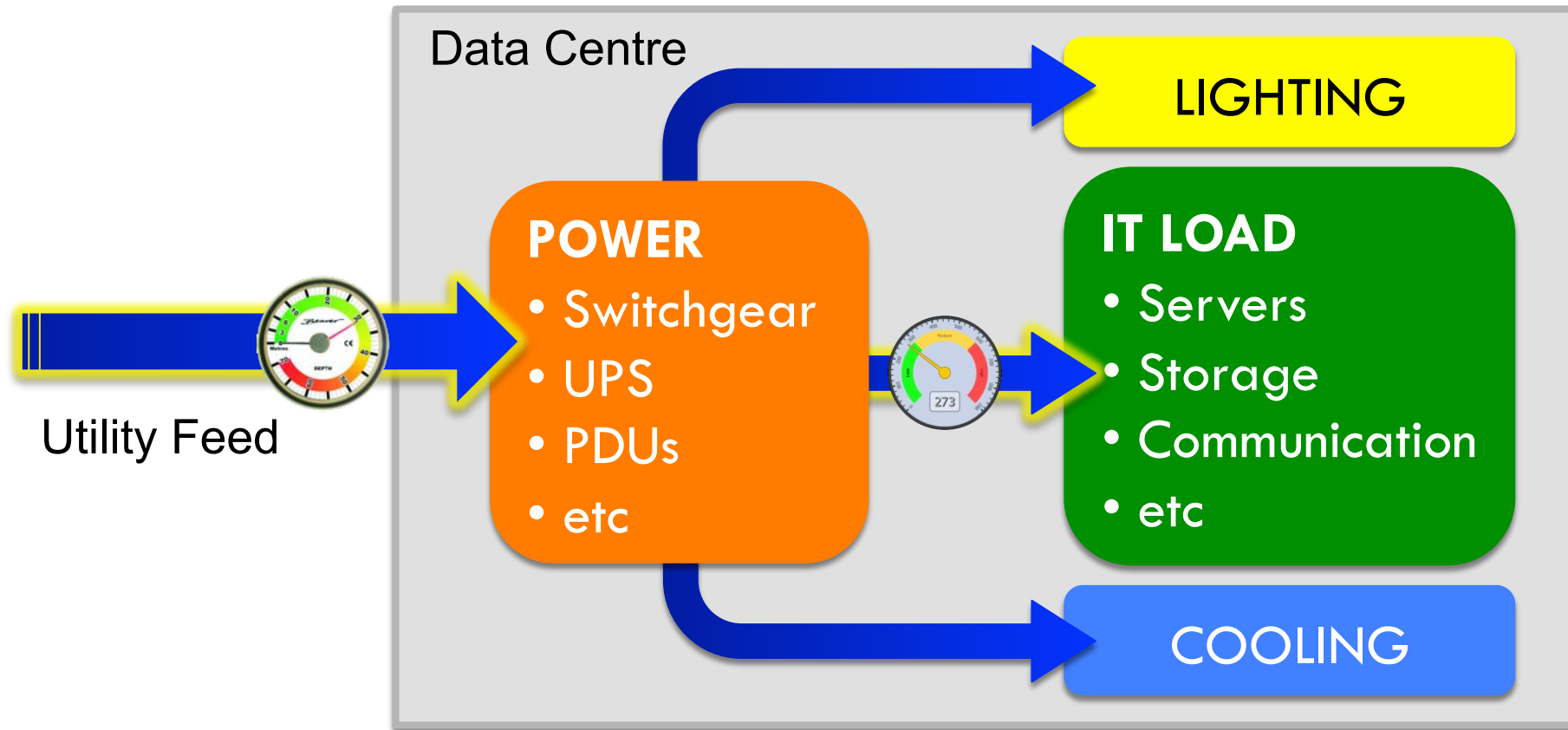
1 Environmental Change Institute (ECI) - Oxford University, "The effectiveness of feedback on energy." <http://www.eci.ox.ac.uk/research/energy/electric-metering.php>, April 2006

2 D. Allen and K. Janda, "The effects of household characteristics and energy use consciousness on the effectiveness of real-time energy use feedback: a pilot study." ACEEE Summer Study on Energy Efficiency in Buildings, 2006

3 Parliamentary Office of Science and Technology, "Postnote Number 319: ICT AND CO2 EMISSIONS." [www.parliament.uk/documents/post/postpn319.pdf](http://www.parliament.uk/documents/post/postpn319.pdf), December 2008



# Power Measurement for Data Centres



$$\text{Data Center Infrastructure Efficiency} = \frac{\text{IT Equipment Power}}{\text{Total Facility Power}}$$



# Existing Monitoring Systems



**Nagios**<sup>®</sup>

<http://www.nagios.org/>



Energy?



**Ganglia**

<http://ganglia.sourceforge.net/>



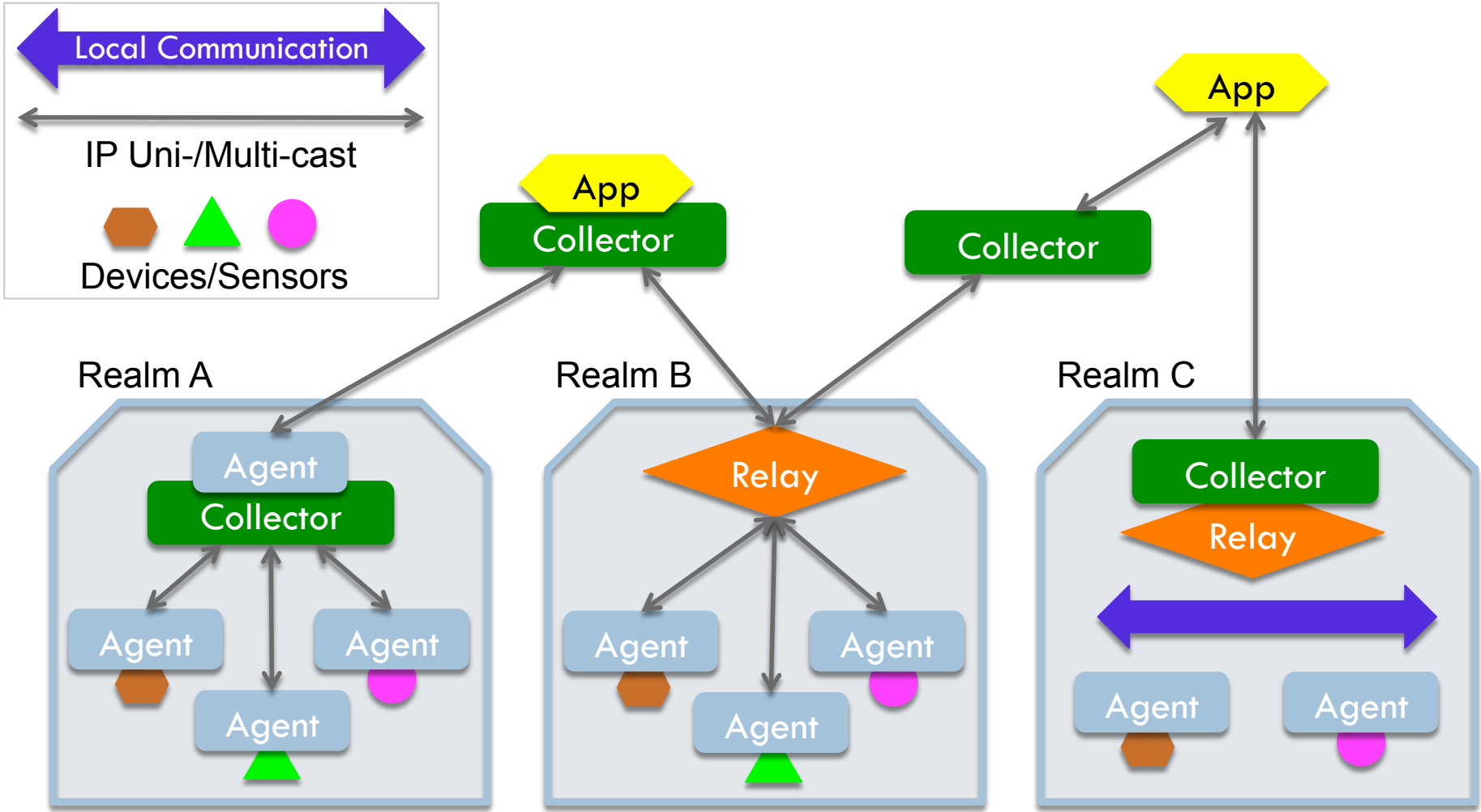
# An Energy Monitor

- Support heterogeneous devices/sensors
- Scalable/Flexible
- Integrable
- Vendor-independent
  - ▣ A universal information model



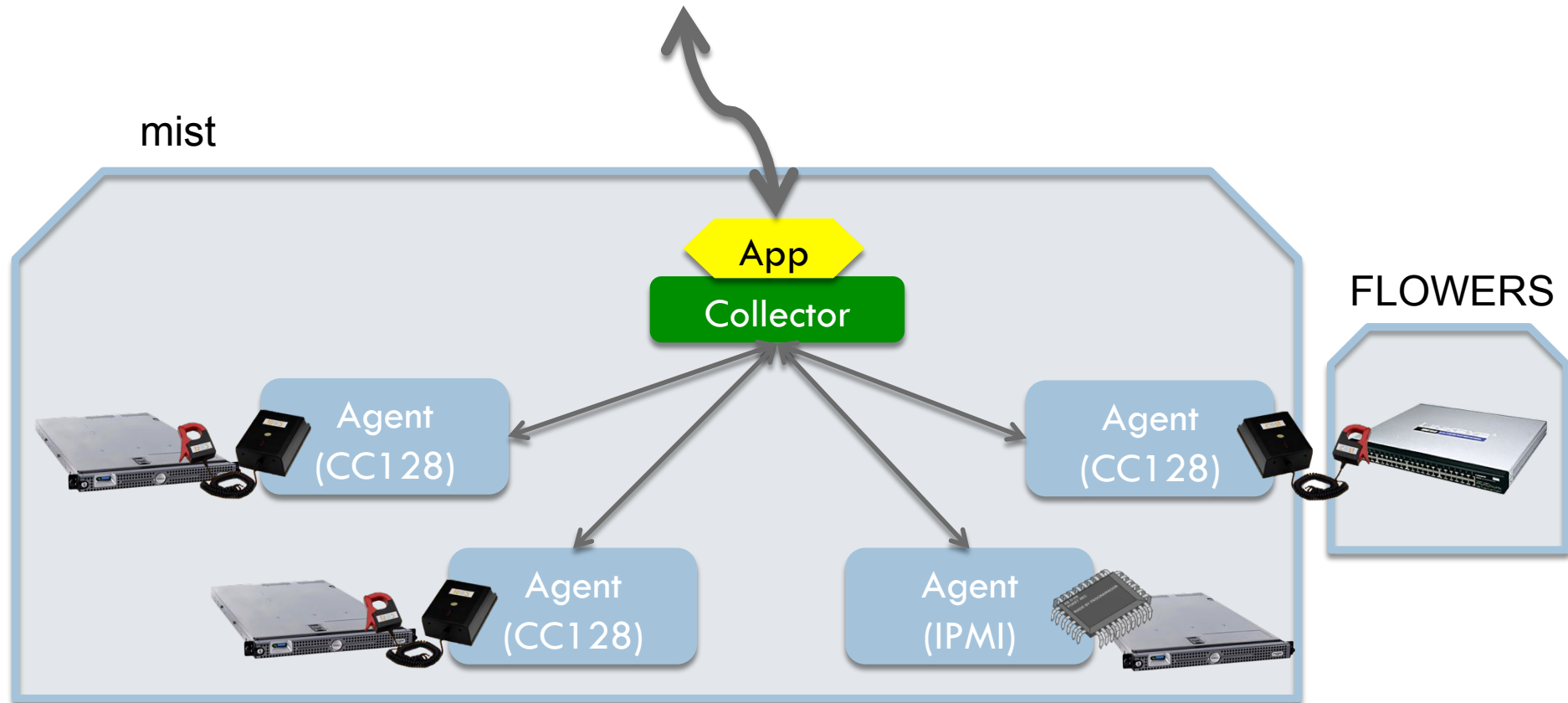


# Architecture



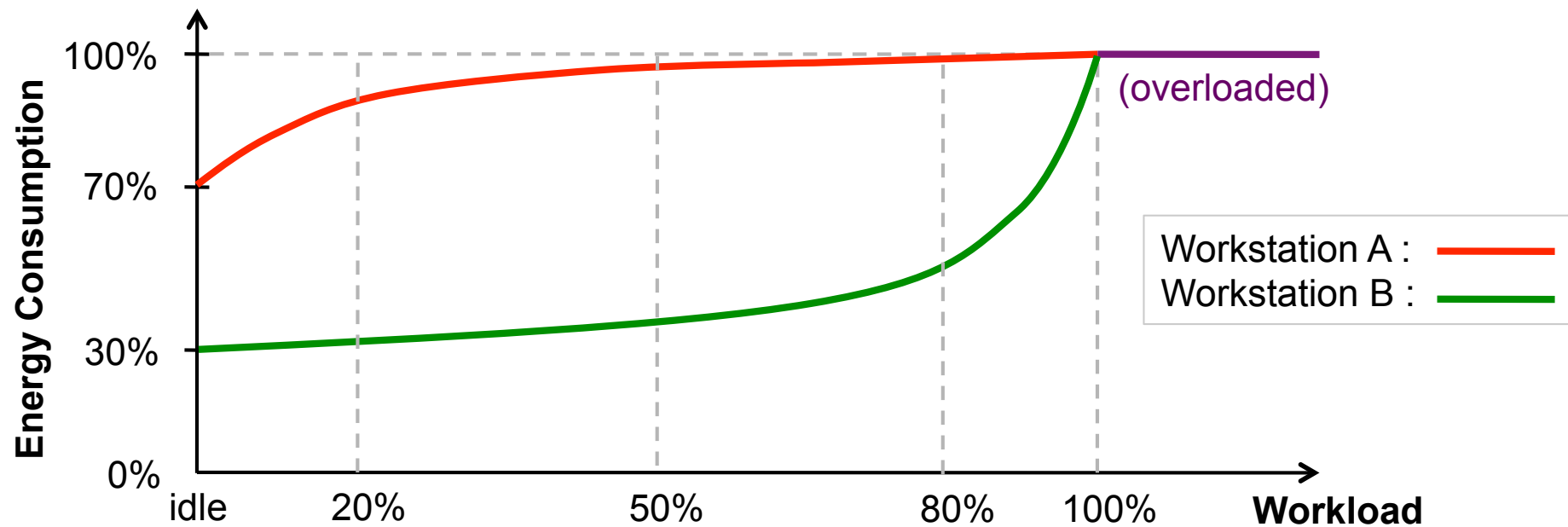
# Demonstration

- <http://mist.cs.st-andrews.ac.uk/em/>



# Applications (1/2)

- Improving conventional system management
  - Energy-aware system management policies
  - Example: *Eucalyptus*<sup>1</sup> Round-Robin vs Greedy scheduling

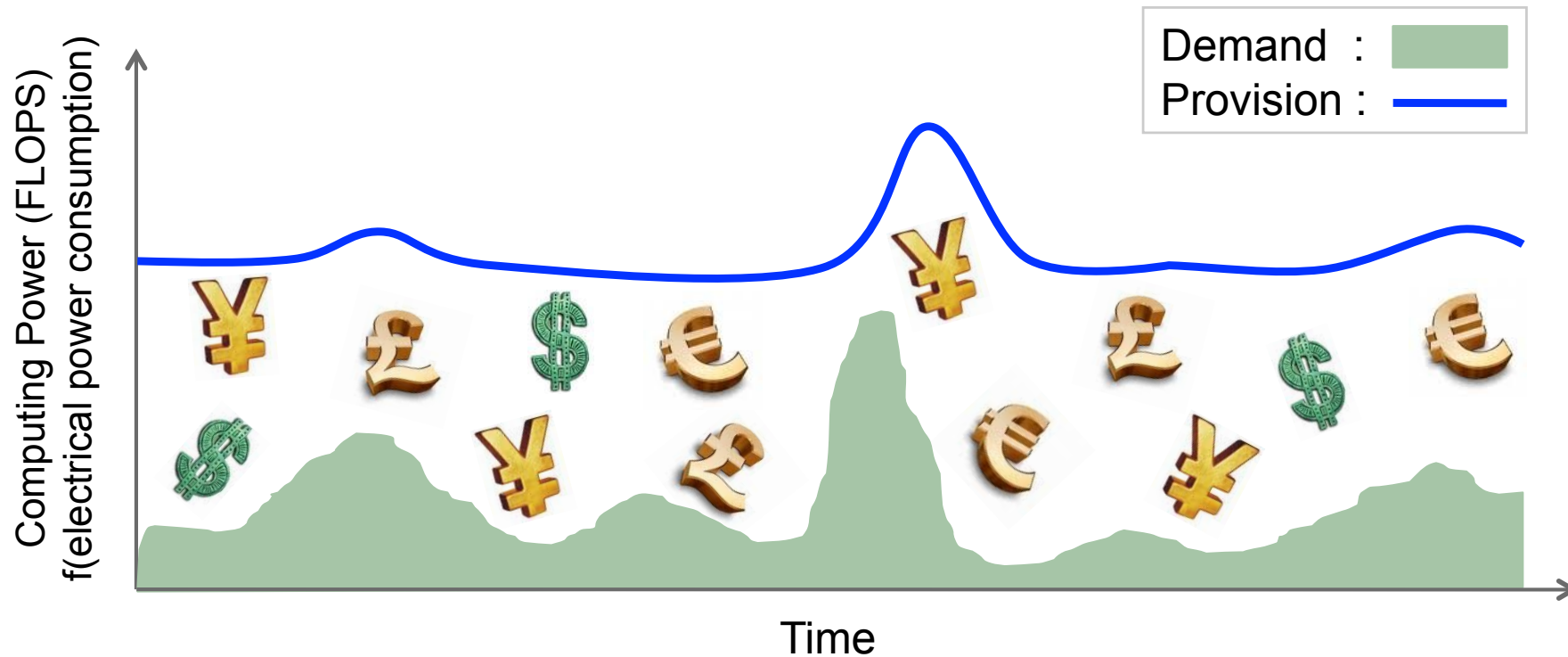


<sup>1</sup> *Eucalyptus* Systems, <http://www.eucalyptus.com/>



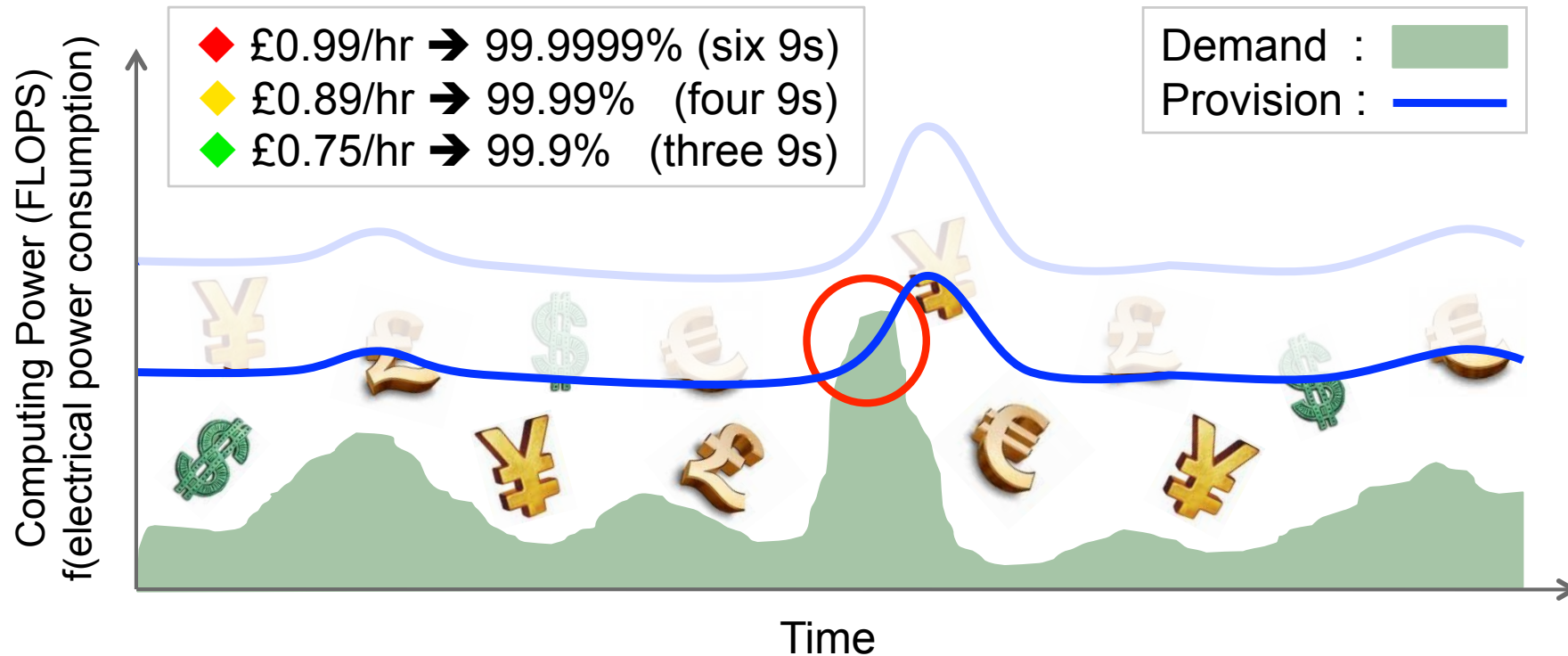
# Applications (2/2)

- Extended power saving for cloud providers
  - ▣ Flexible & energy-aware SLAs



# Applications (2/2 cont.)

- Extended power saving for cloud providers
  - Flexible & energy-aware SLAs



# Thank You !

- “Energy Measurement for the Cloud”
  - ▣ Cloud Computing, Applications and Technologies (CloudCAT) workshop, September 2010
  - ▣ <http://www.cs.st-andrews.ac.uk/~yi/> → “Research”

