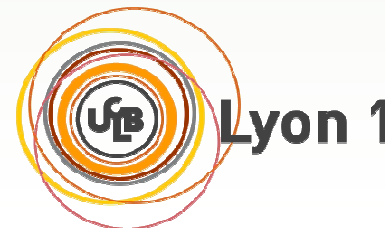
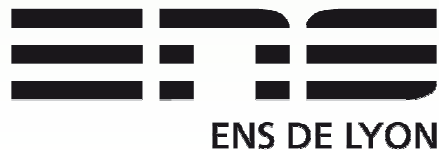


# Energy efficient approach for grids, clouds and networks

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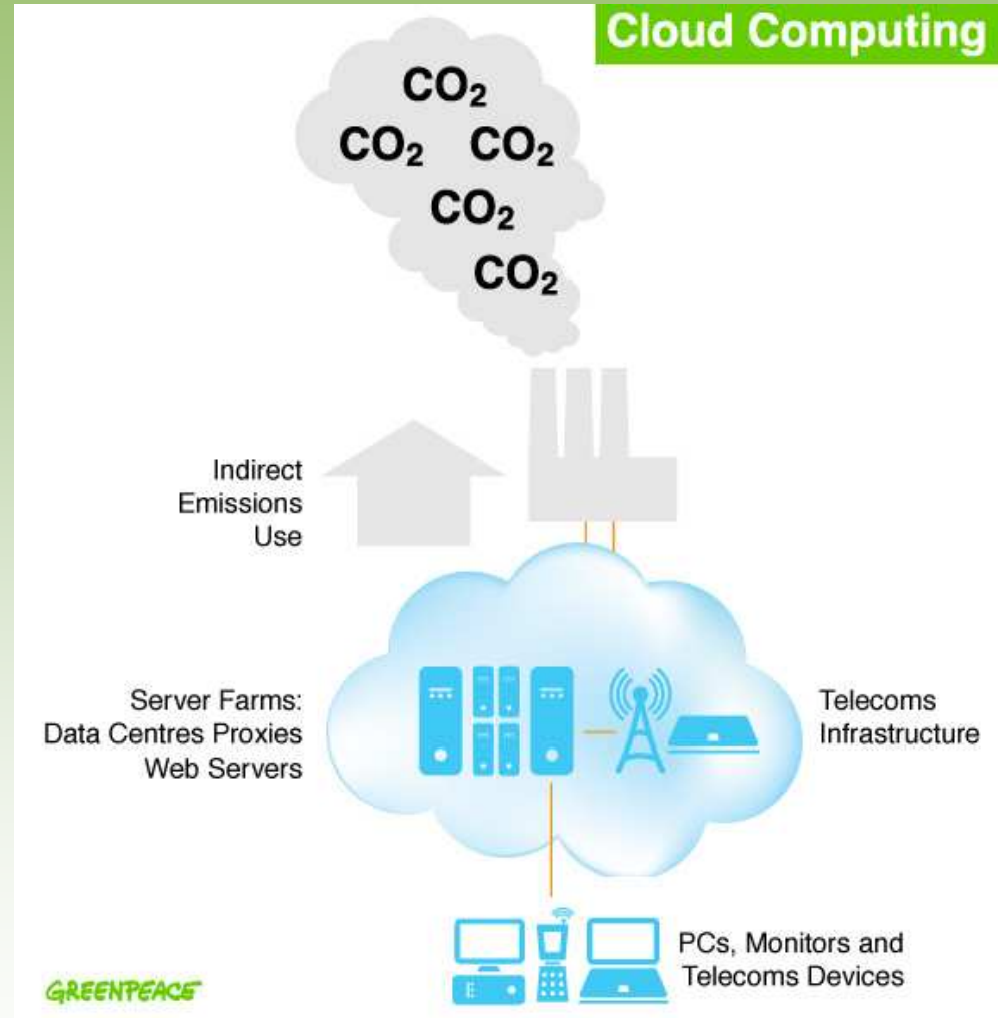
CCGSC2010, Flat Rock, 7th September 2010



# Energy : 1st challenge for large scale systems ?

- Yes ! as important as latency, bandwidth, fault tolerance...
- Exascale systems from 20 to 100MW (F.Cappello)
- How to build such systems and make them energy sustainable/responsible ?
- Hardware can help (component by component)
- Software must be adapted to be scalable but also more energy efficient
- Usage must be energy aware

# Public Concerns !



# Scientific Concerns !



Today

Tomorrow ?

- First approach :evaluate / analyze
- Push simulations vs large experiments
- Reduce amount of co2 consuming research ?



LNCS 4753

## Creating New Learning Experiences on a Global Scale

Second European Conference on Technology Enhanced Learning, EC-TEL 2007  
Crete, Greece, September 2007, Proceedings

 Springer

# Towards Energy Aware Large Scale Systems : open questions

**How to decrease the energy consumption without impacting the performances?**

- How to understand and to analyze the usage and energy consumption of large scale platforms?
- How to monitor lively such usage from pico to large scale views?
- How to design energy aware software frameworks ?
- How to help users to express theirs Green concerns and to express tradeoffs between performance and energy efficiency ?

# Green-IT Leverages

- **Shutdown** : reducing the amount of powered unused resources
- **Slowdown** : adapting the speed of resources to real usage
- **Optimizing** : improving hardware and software for energy reduction purpose (i.e. energy aware libraries)
- **Coordinating** : using large scale approaches to enhance green leverages

# Explosion of initiatives

## For each domain

- Data centers/HPC : Green500, EU CoC
- Grids : The Green Grid / Open Grid Forum
- Storage : SNIA
- Networks : Green Touch / EEE



# Methodology

- Proposing a generic model able to be derivated onto different scenario (Grids, Clouds, Networks)
- Designing software solutions for infrastructures
- Simulating and Validating at medium and large scale



# General approach

Everything is a resource reservation :

- Reserving cpu in HPC and Grids
- Reserving Virtual machines in Clouds
- Reserving Bandwidth in large transport of data
  
- Leverages:
  - Finding and powering the optimal number of resources in front of needs of applications
    - HPC and Grids : switching on/off resources
    - Clouds : switching on/off VMs
    - Networks : lighting or switching off paths, nics, links, routers
  - Adapting « speed » (and consumption) to the need of applications/users
    - HPC, Grids : dvfs
    - Clouds : tuning, capping
    - Networks : adaptive link rate

# The CEPAP model

- Collecting and exposing : usage, energy profiling of applications and infrastructures
- Expressing and Proposing : to deal with tradeoffs between perf and energy, Green Policies
- Agregating resources reservations and usage
- Enforcing Green leverages : switch on/off or adapt performancs
- Predicting usage of infrastructures

# CEPAP

Multi-View Understanding of Large Scale Systems Usage



Monitoring and Analyzing Energy Information



Designing Energy Efficient Frameworks

Grid / Cloud / Network



Site / Data Center / Routers

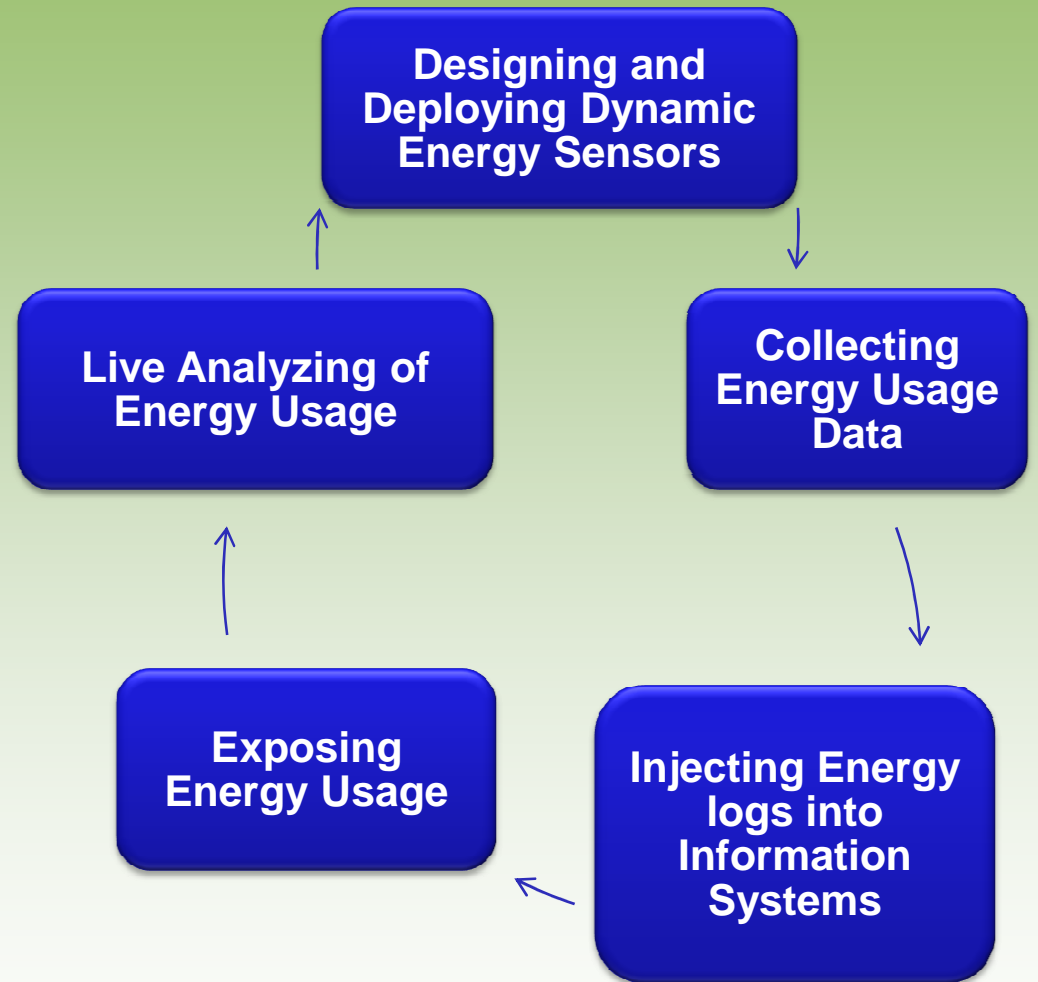
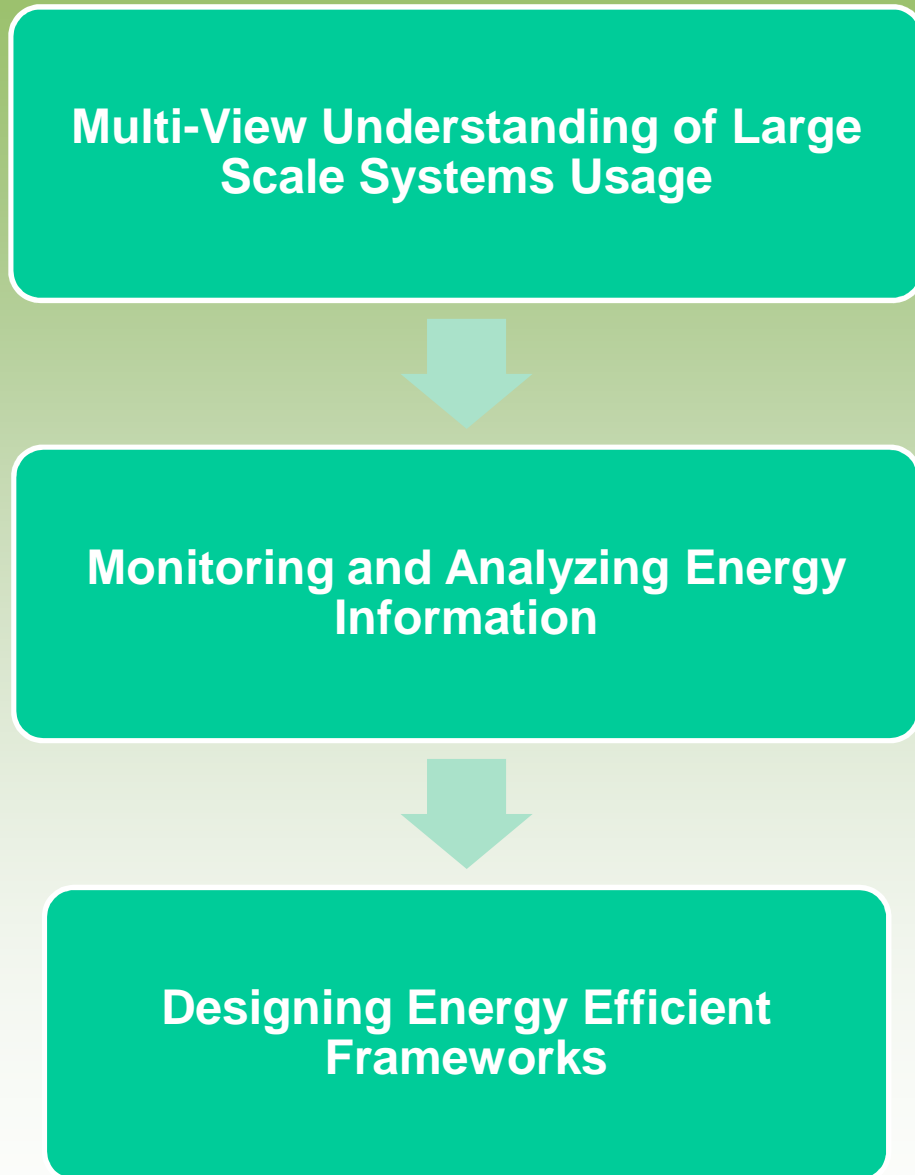


Cluster / LAN



Node / NIC

# CEPAP



# CEPAP

**Multi-View Understanding of Large Scale Systems Usage**



**Monitoring and Analyzing Energy Information**



**Designing Energy Efficient Frameworks**

Energy Aware  
Reservation  
Infrastructure

Prediction  
Systems

Adapted  
Schedulers and  
Resource  
Management

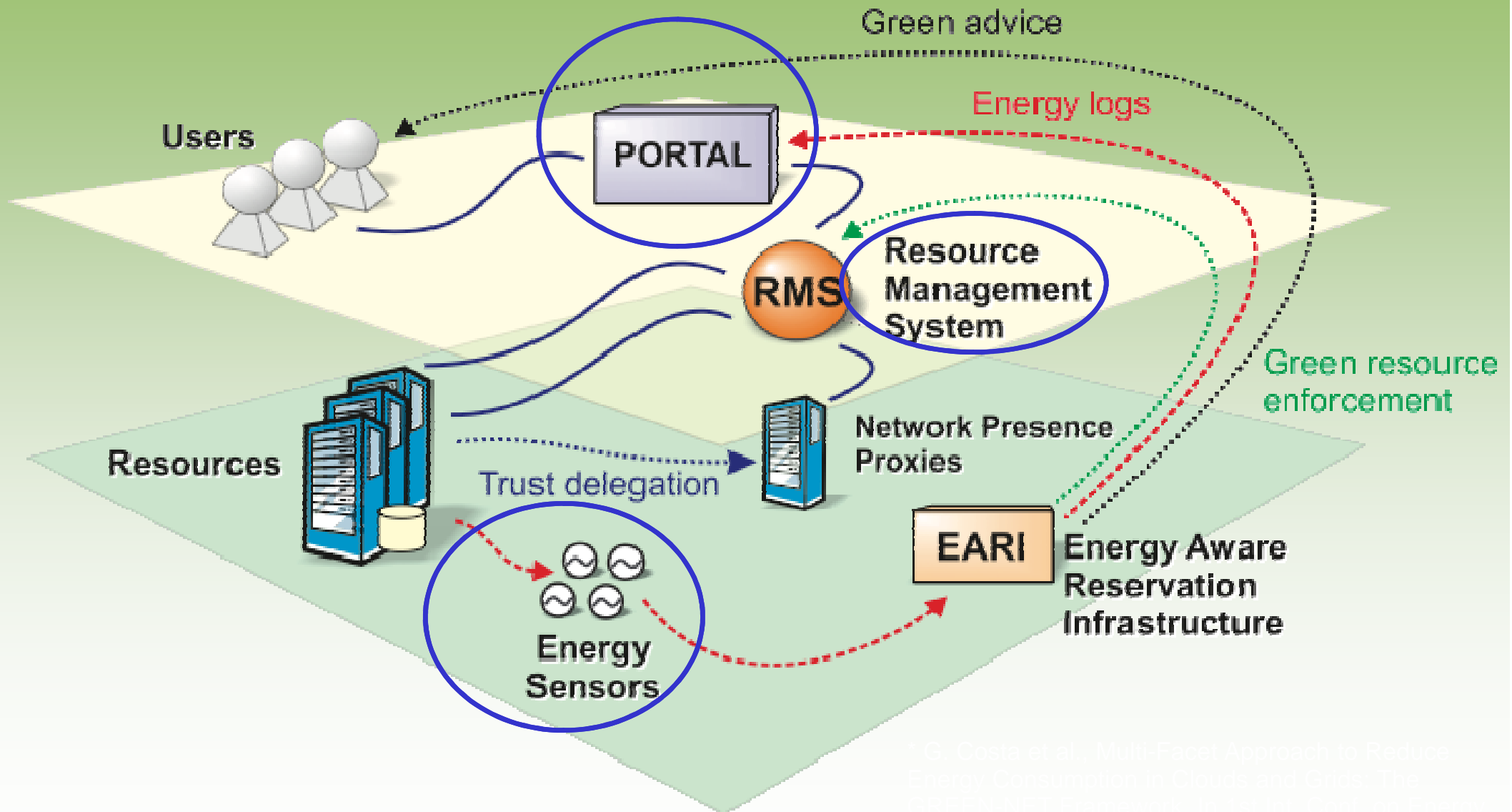
Node and  
Services  
Virtualization

Delegated Trust  
and Network  
Presence

Green Policies  
Support

Node Energy  
Controlers

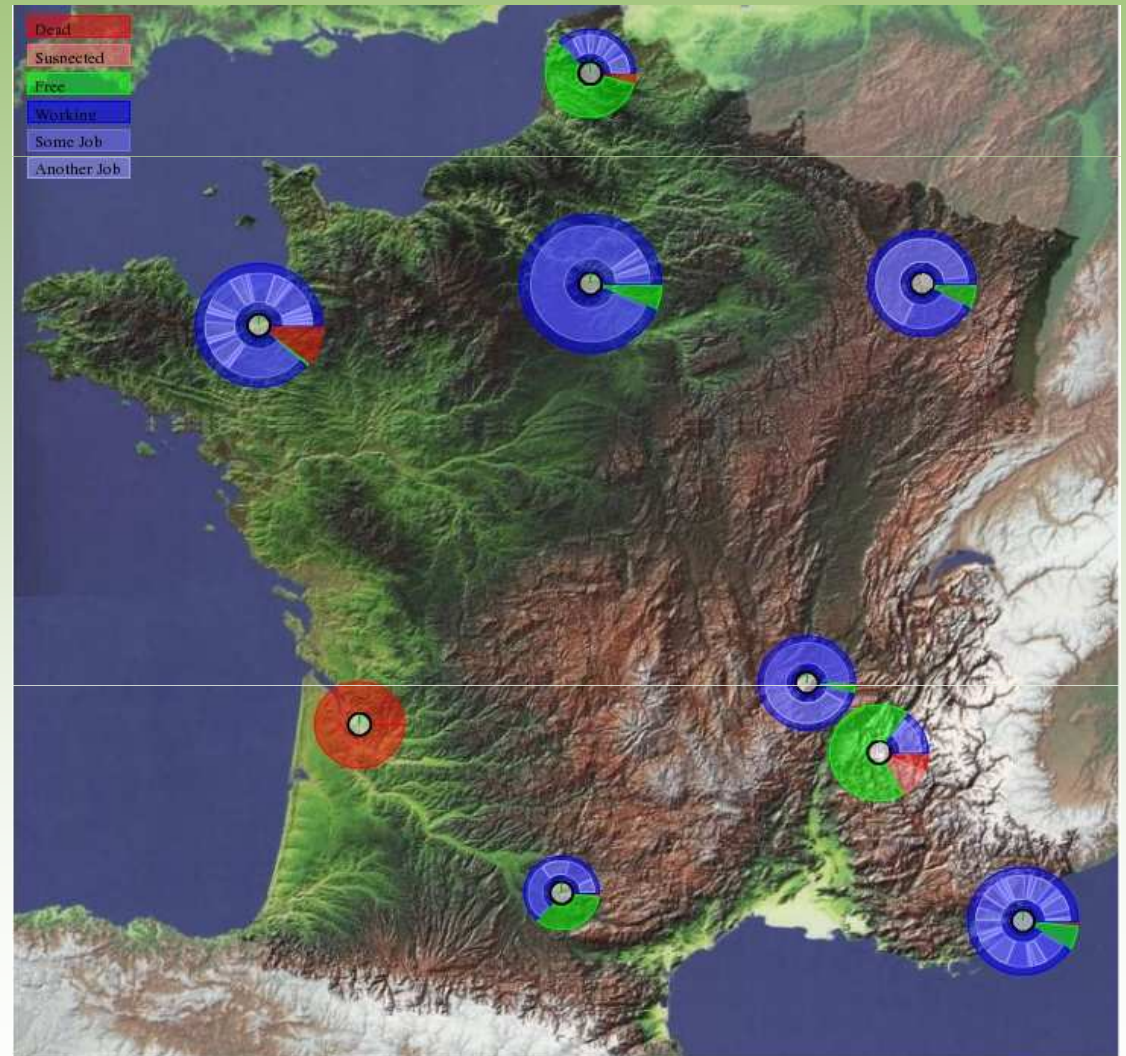
# The CEPAP Framework



\* G. Costa et al., Multi-Facet Approach to Reduce Energy Consumption in Clouds and Grids: The GREENNET Framework for Smart Control on Energy

# 1<sup>st</sup> focus : Collecting and exposing

- Grid'5000
  - French experimental testbed
  - 5000 cores
  - 10 sites



# The Green Grid5000

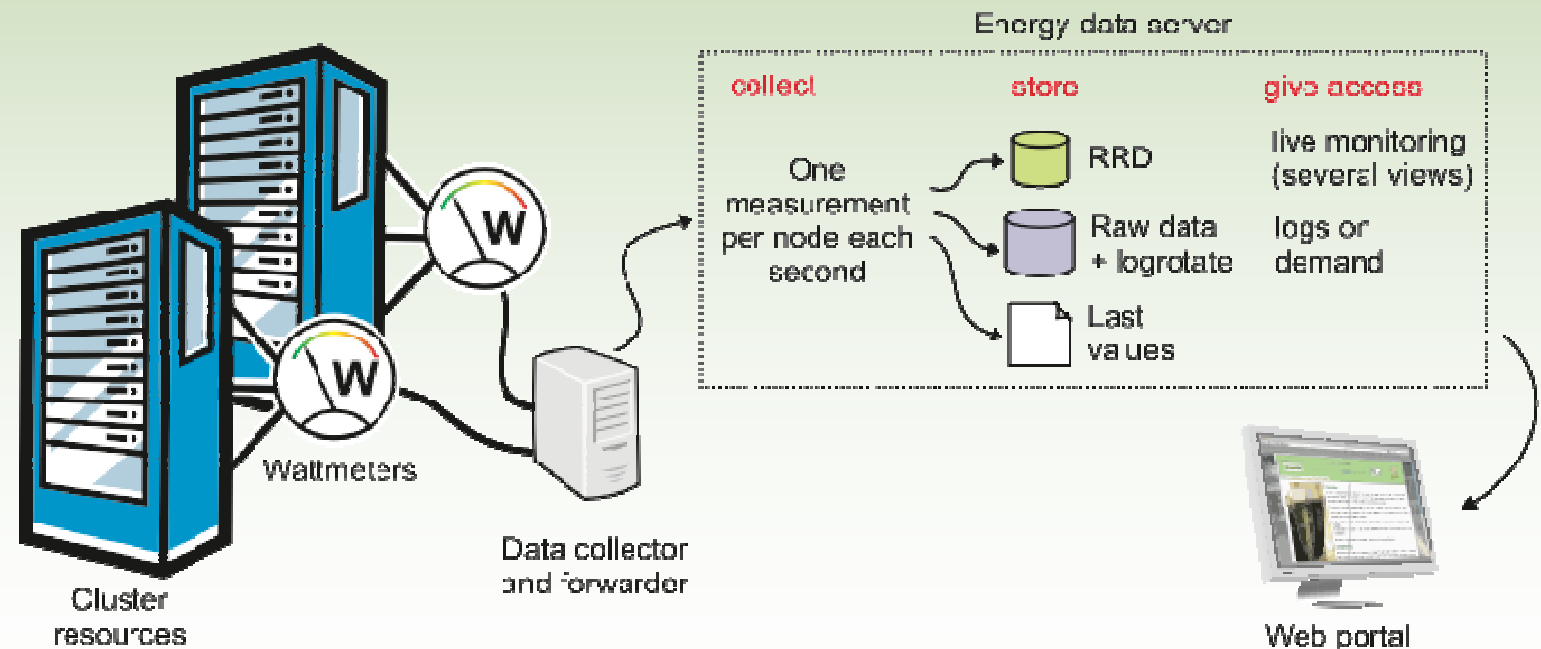
## Energy sensors

6 or 48 ports, communication via serial port

Deployed on three sites of Grid'5000

Library for **interfacing** with **energy sensors**

**Client-side** applications to **obtain** and **store** the energy consumption data



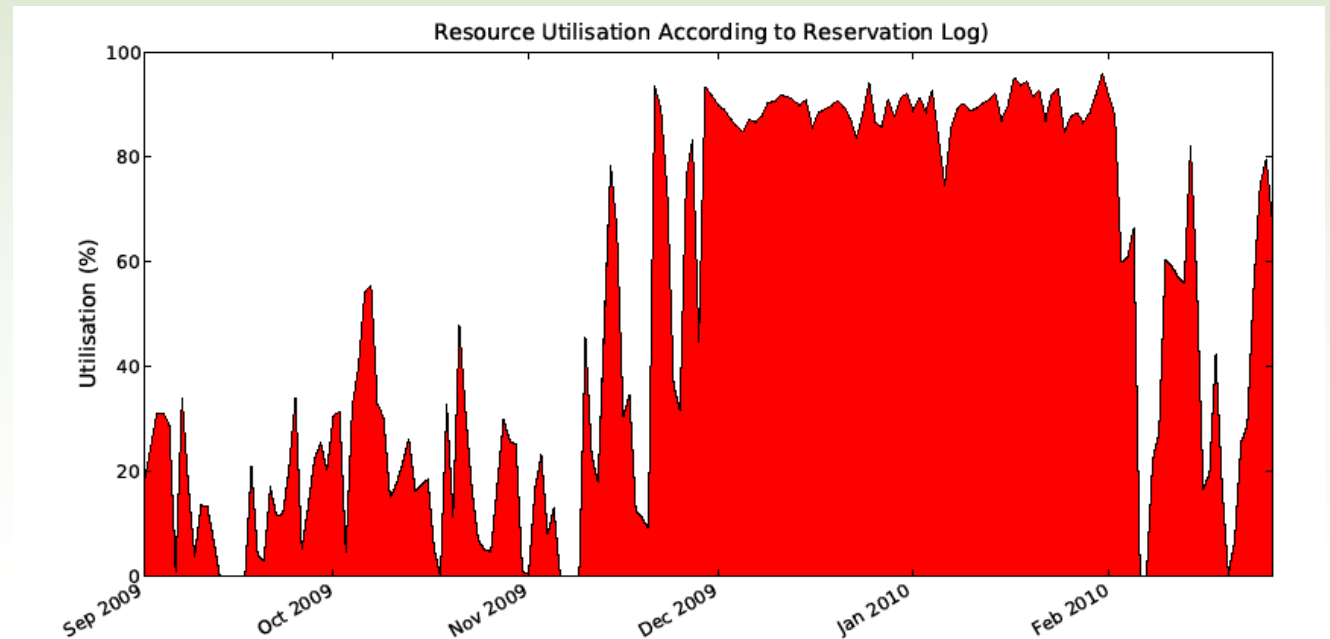
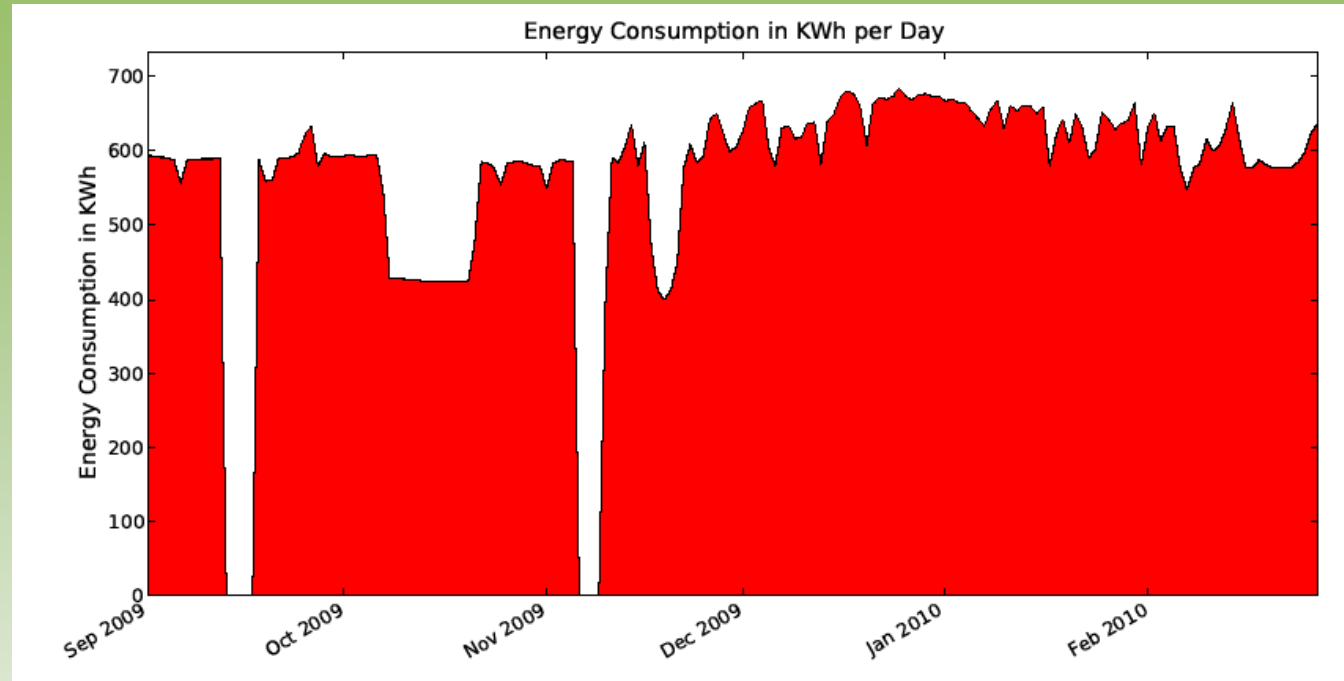


# Electrical consumption / Usage

Periodicity of energy measurements:

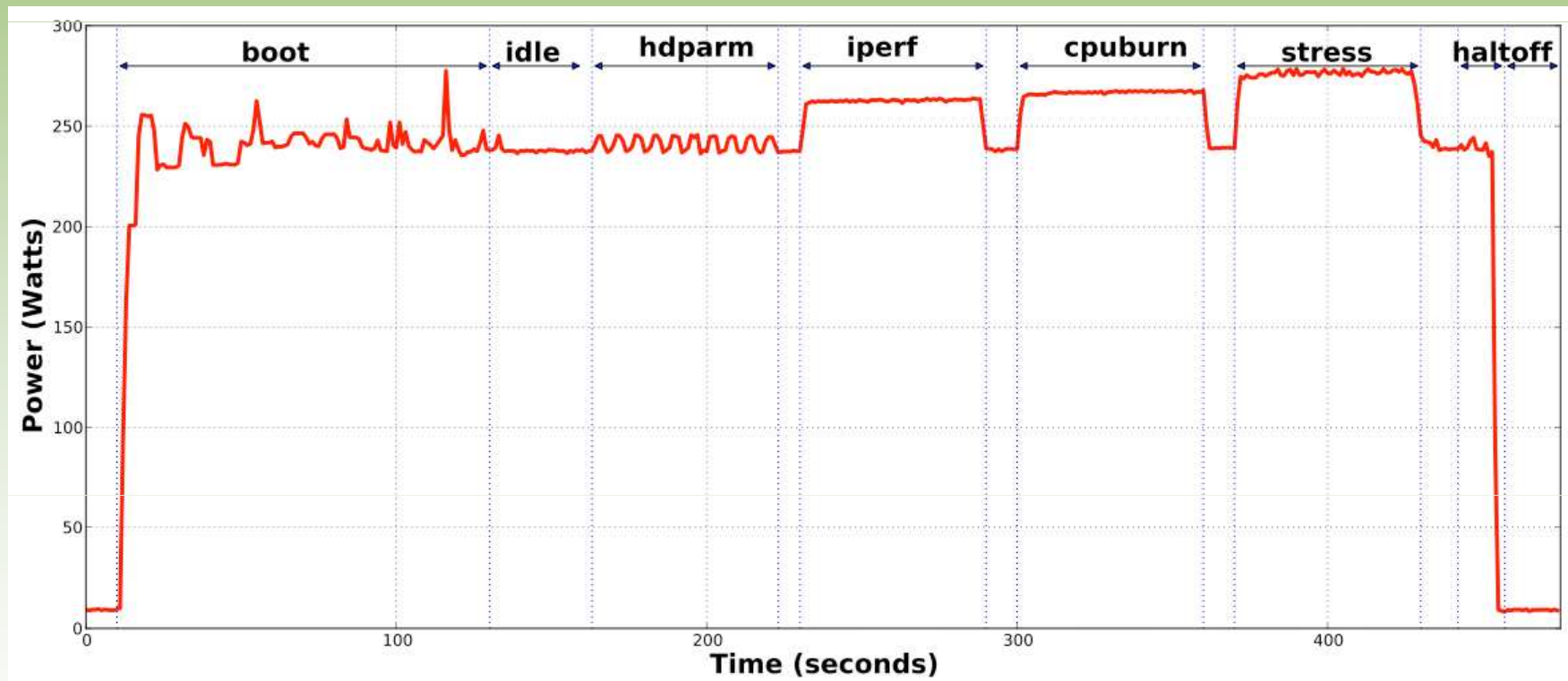
One measurement per **second** for each equipment

\*



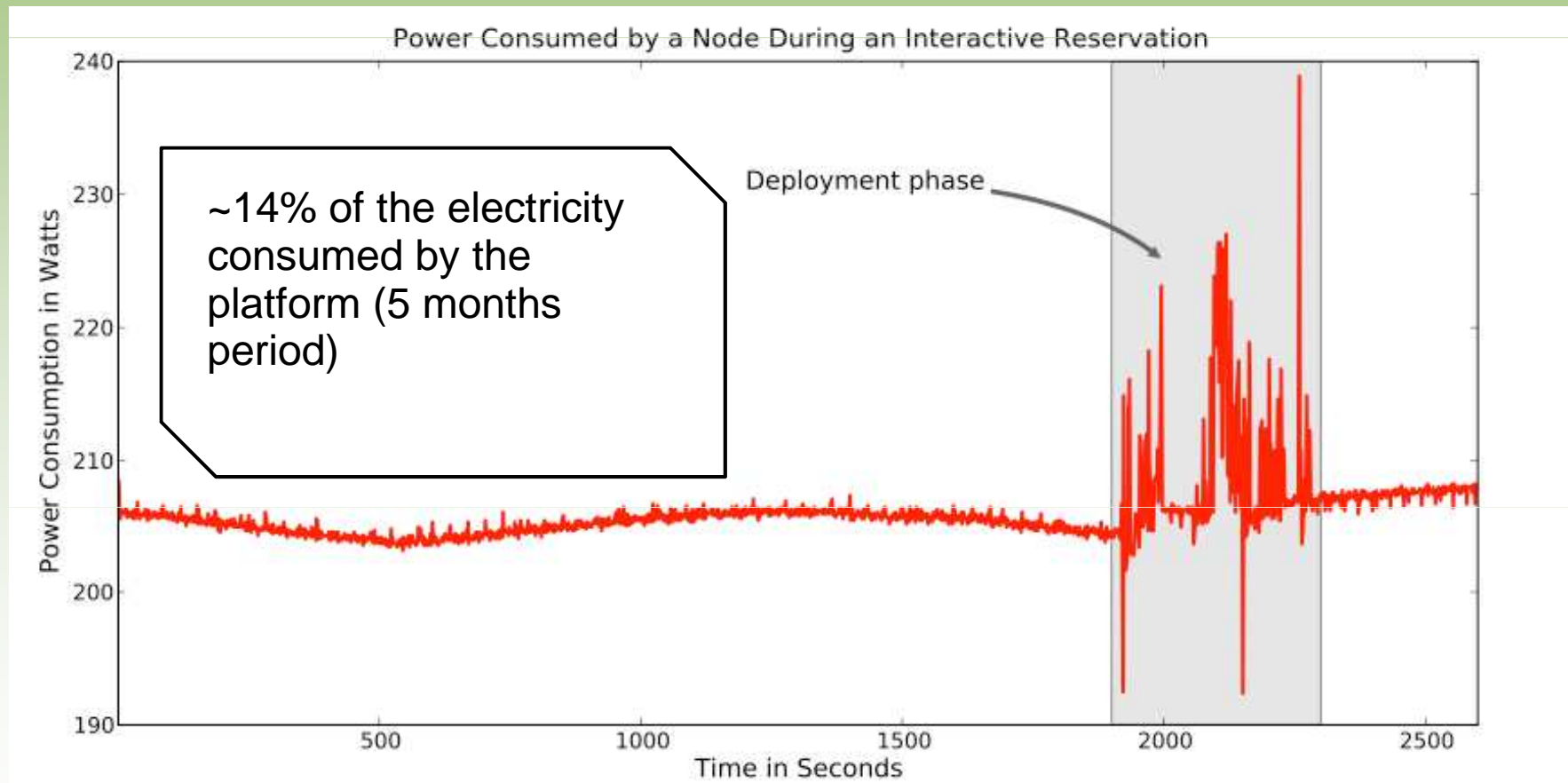
# Example I : Profiling applications

Profiling the energy consumption of applications



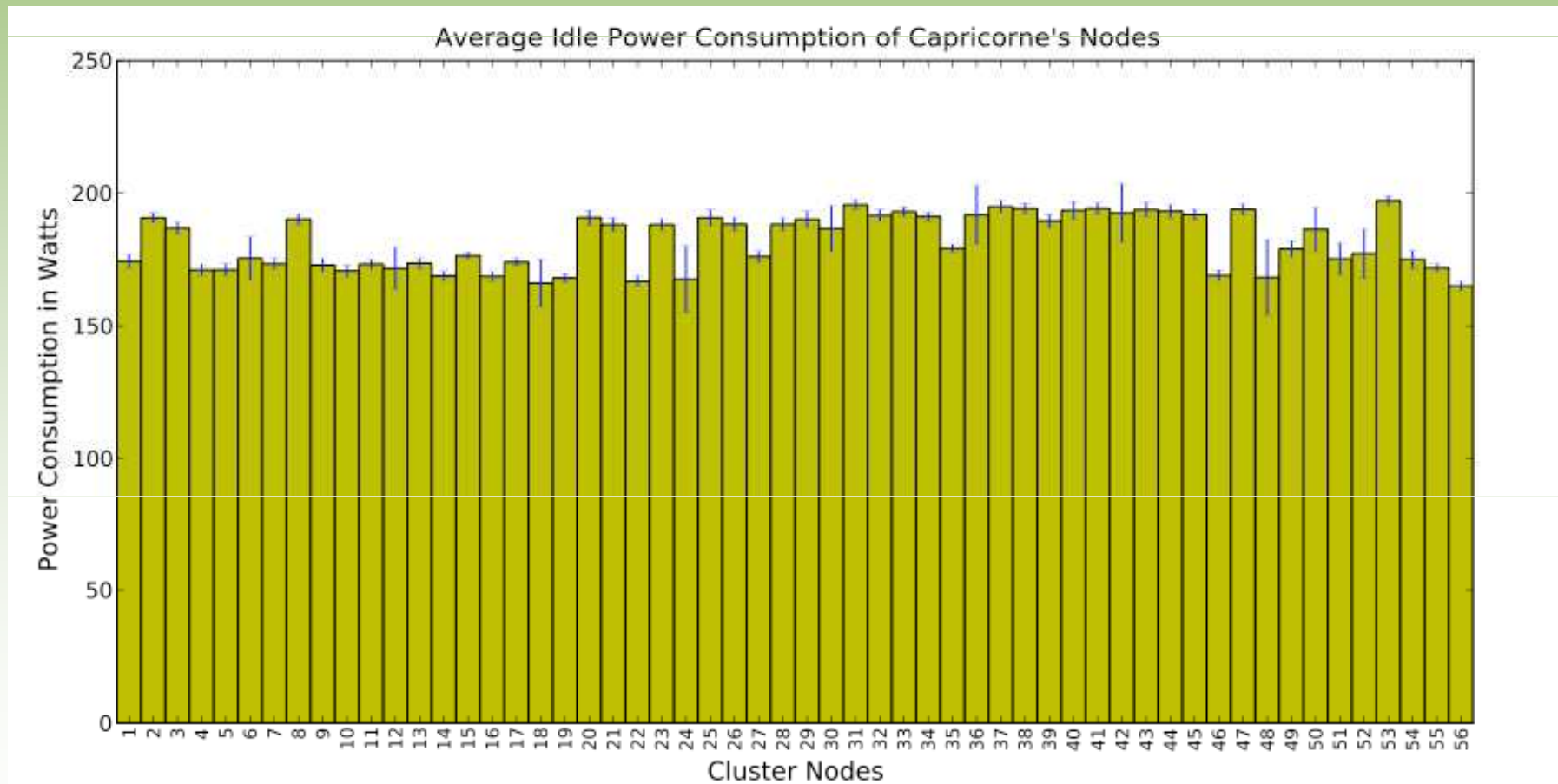
# Example II : detecting anomalies

Improving frameworks/middleware and policies



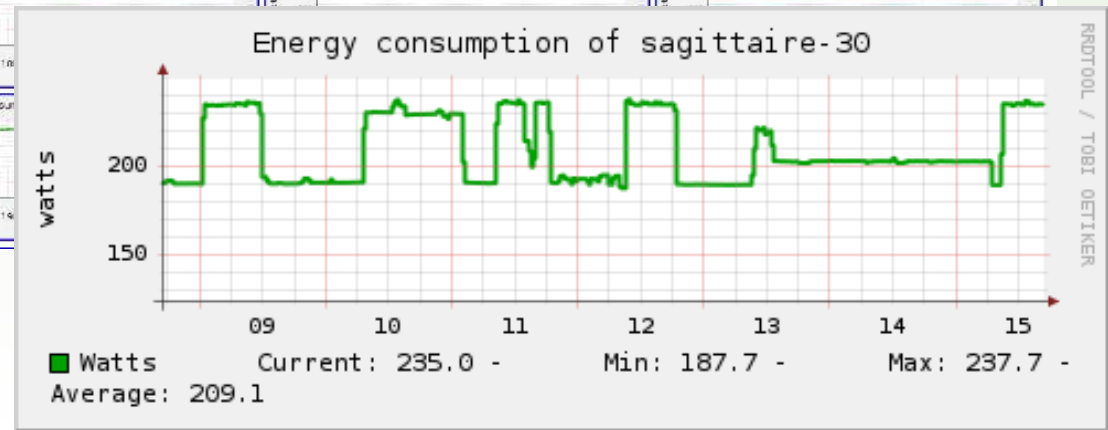
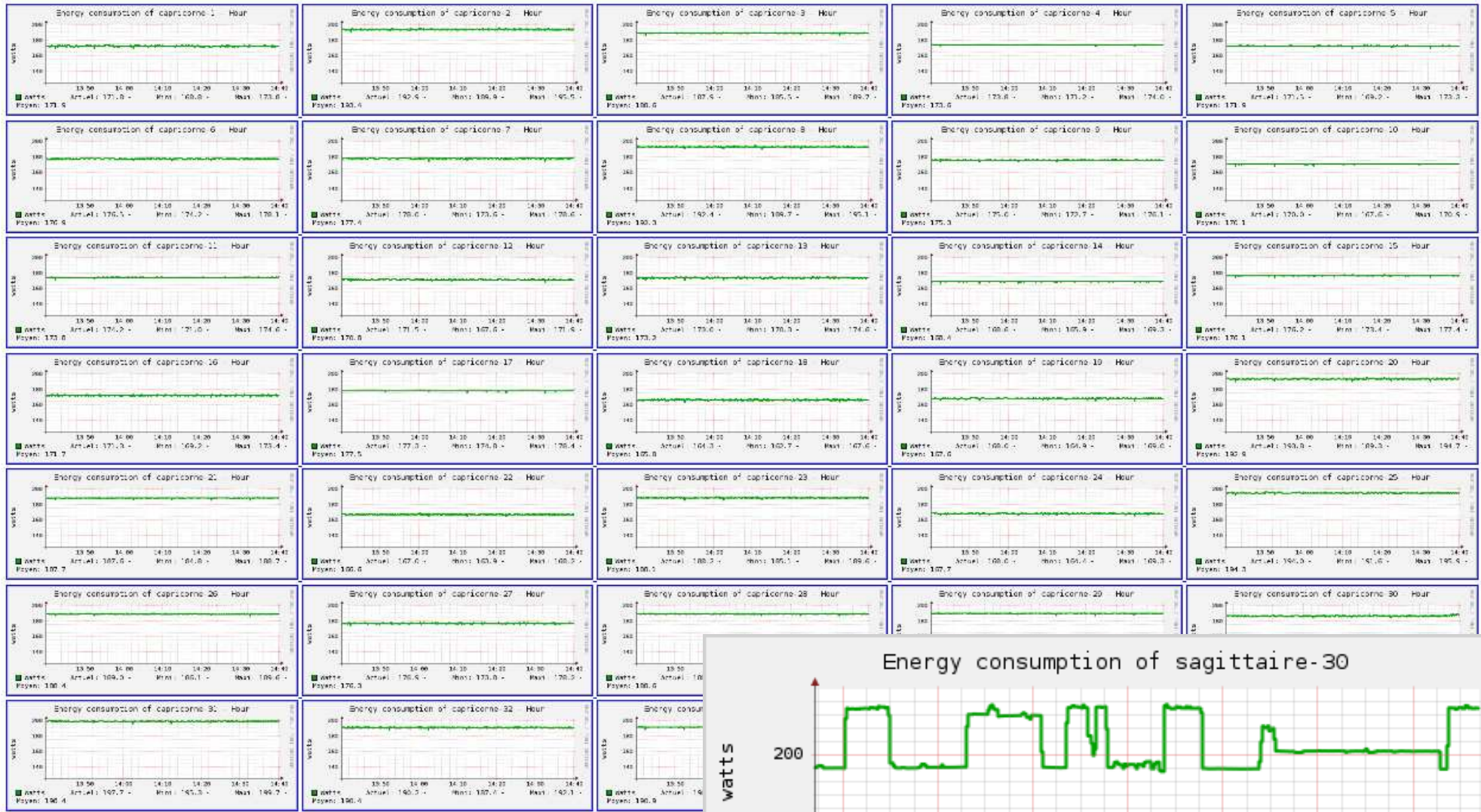
# Example III : providing global views

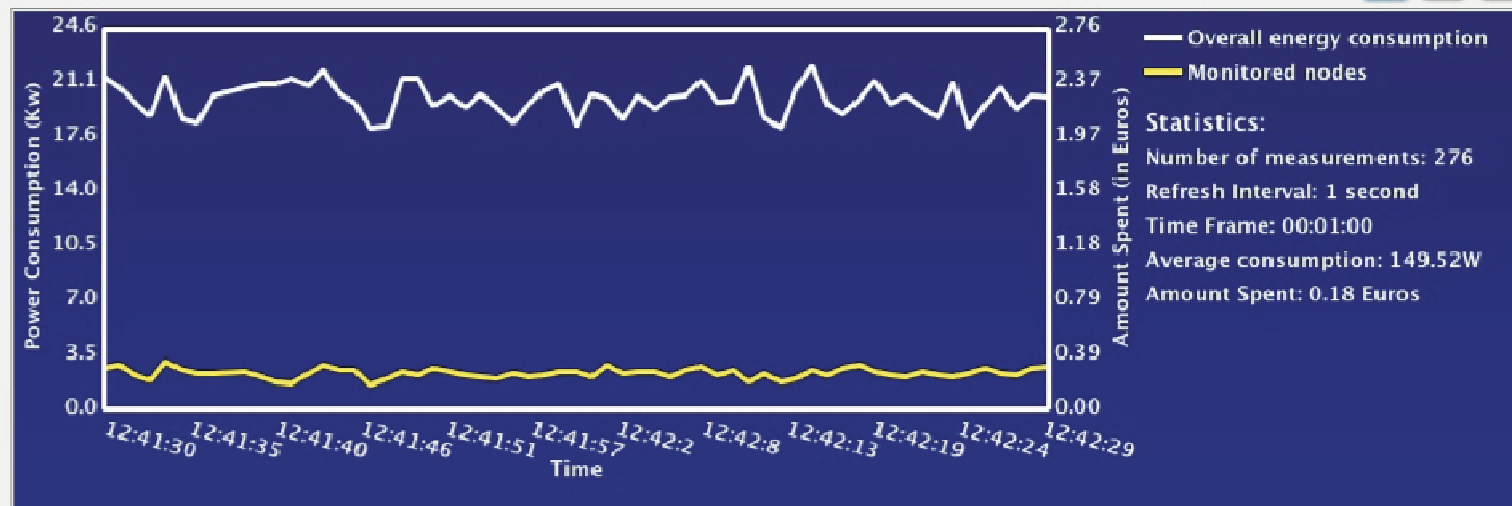
Understanding the overall infrastructure



# Large scale energy exposing

## Energy Information of Lyon Grid5000 site

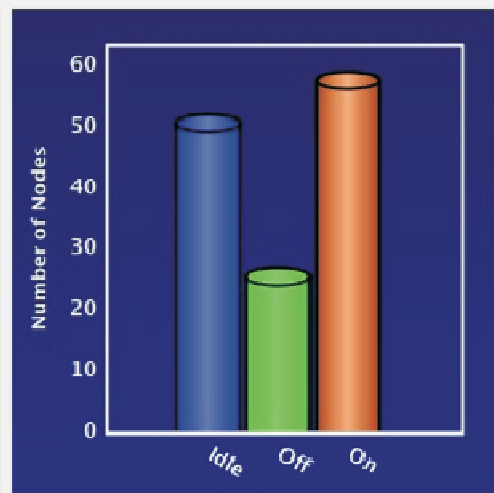




Status of Resources:

sagit-1 74.81W ●	sagit-11 294.94W ●	sagit-21 221.42W ●	sagit-31 163.69W ●	sagit-41 43.65W ●	sagit-51 193.71W ●	sagit-61 236.40W ●	sagit-71 64.54W ●	capric-2 241.65W ●	capric-3 192.85W ●	capric-15 52.98W ●	capric-25 14.16W ●	capric-32 83.97W ●	capric-42 180.02W ●	capric-52 226.64W ●
sagit-2 162.28W ●	sagit-12 276.10W ●	sagit-22 19.56W ●	sagit-32 274.28W ●	sagit-42 55.37W ●	sagit-52 73.74W ●	sagit-62 189.81W ●	sagit-72 203.15W ●	capric-3 192.85W ●	capric-4 172.71W ●	capric-16 70.33W ●	capric-26 261.25W ●	capric-33 130.27W ●	capric-43 40.37W ●	capric-53 226.64W ●
sagit-3 253.17W ●	sagit-13 257.72W ●	sagit-23 74.62W ●	sagit-33 10.06W ●	sagit-43 118.46W ●	sagit-53 220.34W ●	sagit-63 214.84W ●	sagit-73 133.10W ●	capric-4 172.71W ●	capric-5 22.49W ●	capric-17 14.22W ●	capric-27 12.46W ●	capric-34 16.68W ●	capric-44 61W ●	capric-54 43.12W ●
sagit-4 290.73W ●	sagit-14 32.88W ●	sagit-24 203.23W ●	sagit-34 225.22W ●	sagit-44 8.775W ●	sagit-54 245.74W ●	sagit-64 199.51W ●	sagit-74 234.59W ●	capric-5 22.49W ●	capric-6 29.49W ●	capric-18 32.41W ●	capric-28 246.45W ●	capric-35 113.88W ●	capric-45 171.48W ●	capric-55 171.48W ●
sagit-5 11.05W ●	sagit-15 84.01W ●	sagit-25 40.13W ●	sagit-35 298.92W ●	sagit-45 89.05W ●	sagit-55 245.91W ●	sagit-65 36.89W ●	sagit-75 29.49W ●	capric-6 29.49W ●	capric-7 43.65W ●	capric-19 19.43W ●	capric-29 113.88W ●	capric-36 11.7W ●	capric-46 11.7W ●	capric-56 171.48W ●
sagit-6 199.85W ●	sagit-16 87.00W ●	sagit-26 121.88W ●	sagit-36 166.51W ●	sagit-46 142.07W ●	sagit-56 69.71W ●	sagit-66 142.63W ●	sagit-76 55.75W ●	capric-7 43.65W ●	capric-8 180.02W ●	capric-20 113.88W ●	capric-30 113.88W ●	capric-37 11.7W ●	capric-47 11.7W ●	capric-57 171.48W ●
sagit-7 167.38W ●	sagit-17 103.75W ●	sagit-27 259.07W ●	sagit-37 285.37W ●	sagit-47 214.58W ●	sagit-57 289.71W ●	sagit-67 95.29W ●	sagit-77 287.10W ●	capric-8 180.02W ●	capric-9 113.88W ●	capric-21 113.88W ●	capric-31 113.88W ●	capric-38 11.7W ●	capric-48 11.7W ●	capric-58 171.48W ●
sagit-8 12.01W ●	sagit-18 221.81W ●	sagit-28 36.93W ●	sagit-38 213.72W ●	sagit-48 12.82W ●	sagit-58 47.50W ●	sagit-68 244.97W ●	sagit-78 150.37W ●	capric-9 113.88W ●	capric-10 113.88W ●	capric-22 113.88W ●	capric-32 113.88W ●	capric-39 11.7W ●	capric-49 11.7W ●	capric-59 171.48W ●
sagit-9 153.28W ●	sagit-19 69.04W ●	sagit-29 201.03W ●	sagit-39 77.61W ●	sagit-49 2.38W ●	sagit-59 298.60W ●	sagit-69 25.05W ●	sagit-79 37.01W ●	capric-10 113.88W ●	capric-11 113.88W ●	capric-23 113.88W ●	capric-33 113.88W ●	capric-40 11.7W ●	capric-50 171.48W ●	capric-60 171.48W ●
sagit-10 137.56W ●	sagit-20 216.04W ●	sagit-30 207.96W ●	sagit-40 129.01W ●	sagit-50 223.91W ●	sagit-60 244.97W ●	sagit-70 14.47W ●	capric-1 86.08W ●	capric-11 215.51W ●	capric-12 173.91W ●	capric-24 113.88W ●	capric-34 113.88W ●	capric-41 119.56W ●	capric-51 171.48W ●	capric-61 171.48W ●

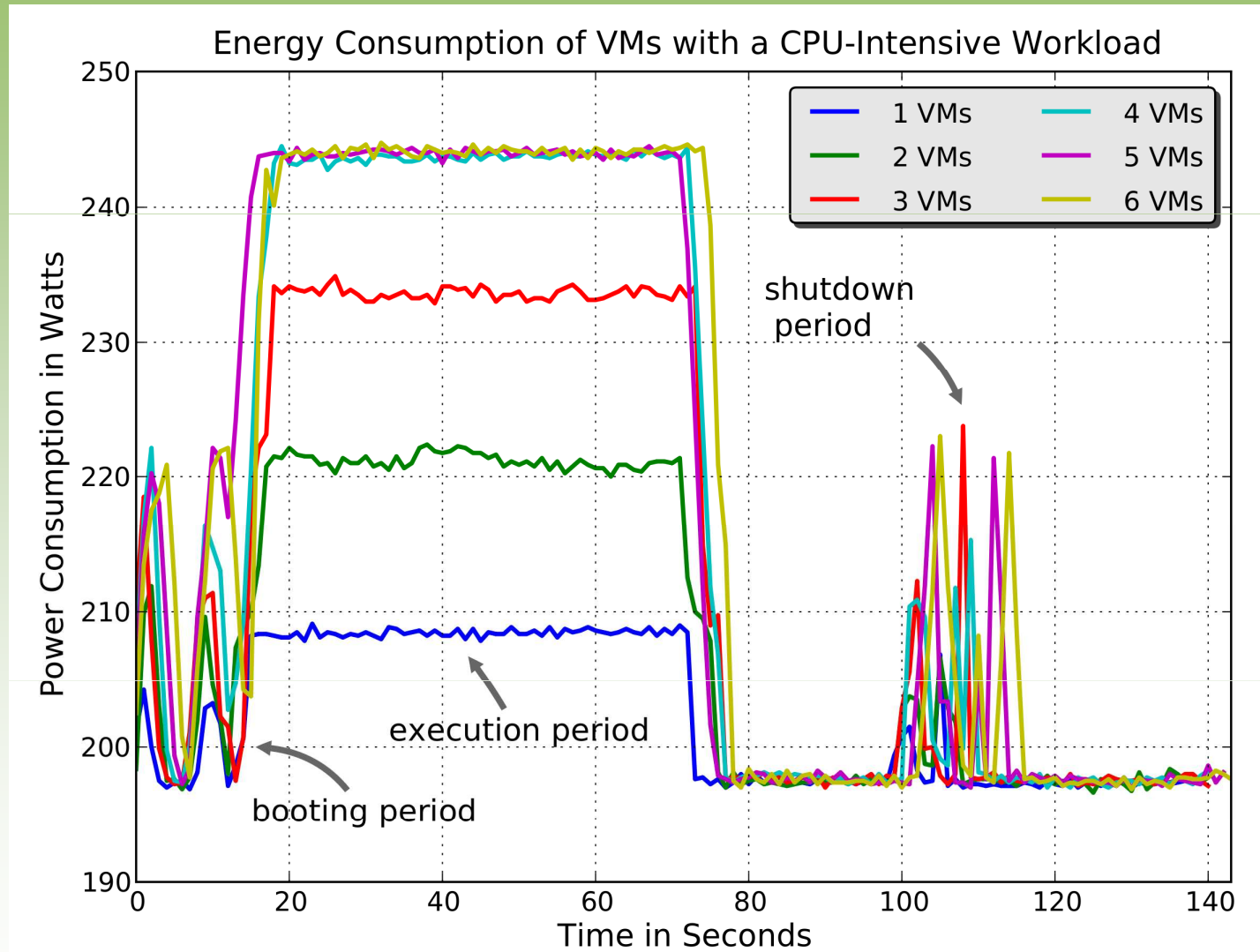
■ Resource on   
 ■ Resource idle   
 ■ Resource off   
 ● Resource monitored



# Focus 2 : GOC

- Designing the Green Open Cloud architecture (GOC) based on the CEPAP model
- Supporting advanced features like live migration, tuning capping for agregating

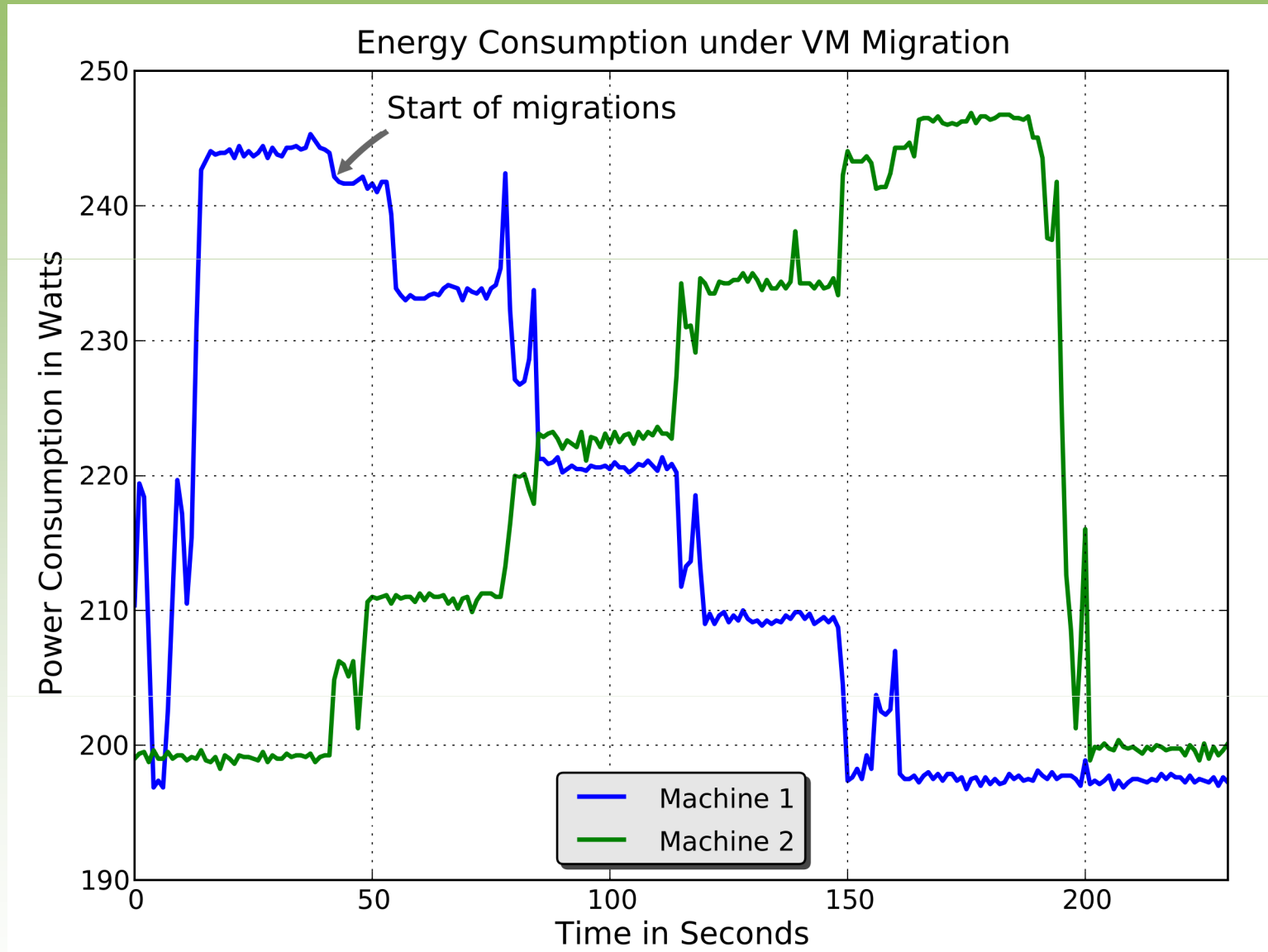
# Boot, Run and Halt



- 6% increase of energy with 1 VM running

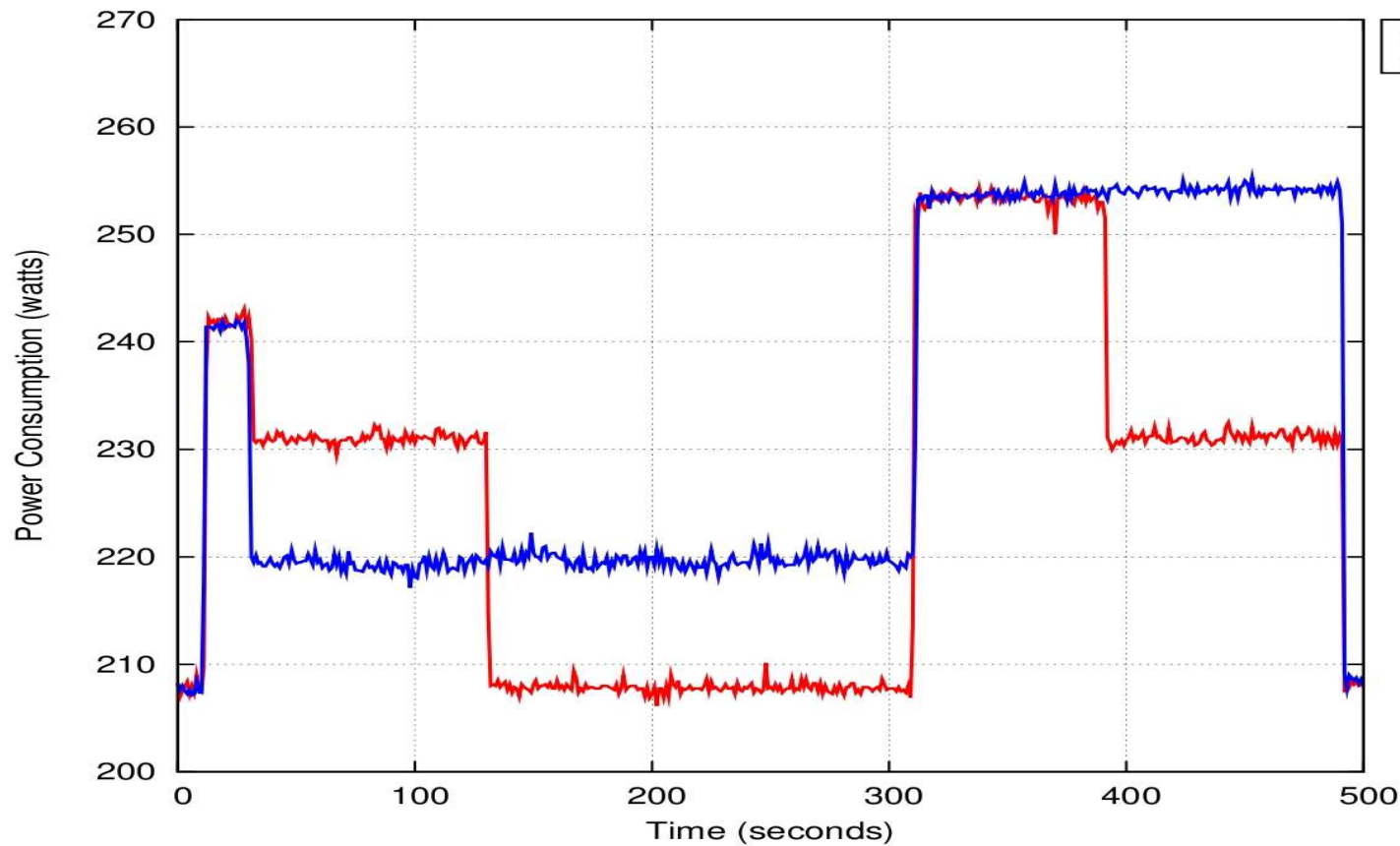
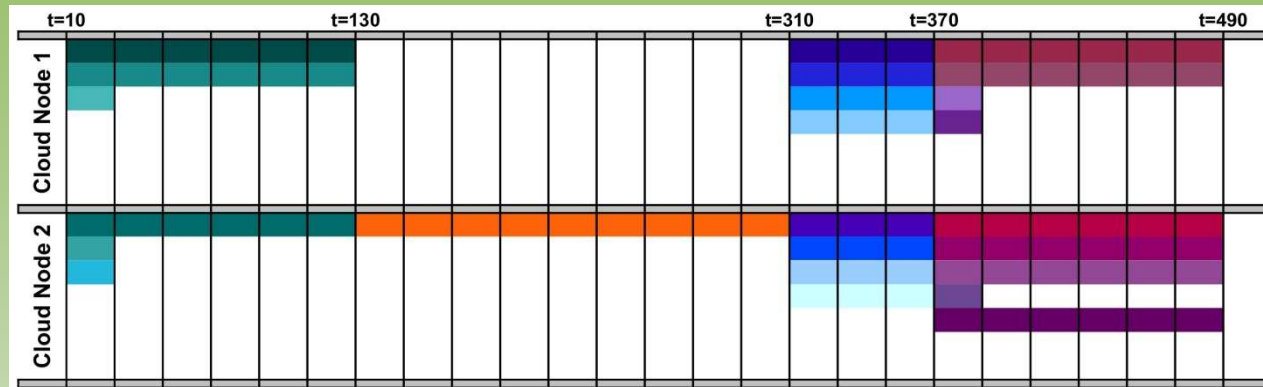


# Migration



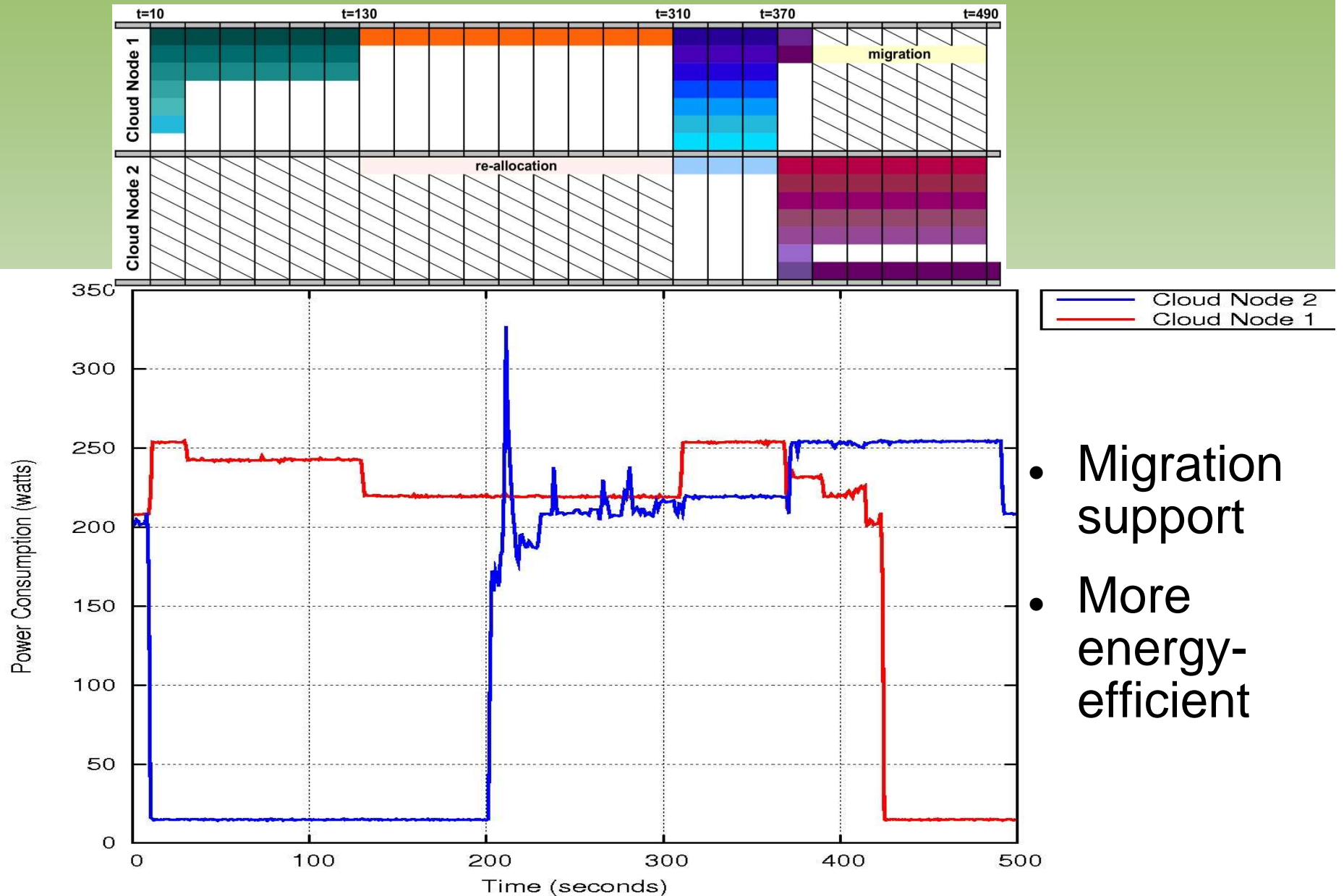
- Bad moment in energy during the migration

# Load balancing tasks in VMs



- Identical nodes
- Energy levels

# Unbalanced with Green Scenario



# Contributions and Perspectives

- Energy aspects change the way we design applications, protocols, services and policies (i.e. load balancing is not always the best solution)
- Challenge : design energy proportional equipments and frameworks (computing, memory or network usage)
- Current works : energy efficiency in Green Wired Networks

# Questions?

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Thanks to A.C. Orgerie, M. Dias de Assuncao, J.P. Gelas

