ECO$_2$Clouds

Experimental Awareness of CO_2
in Federated Cloud Sourcing

Newsletter September 2014

The ECO$_2$Clouds project has developed strategies and mechanisms that can aid effective utilization of federated cloud resources while reducing energy consumption and CO_2 emissions of cloud applications.
ECO2Clouds provides a challenging and innovative approach to Cloud computing service delivery by:

- Developing extensions and mechanisms for cloud application programming interfaces and monitoring mechanisms to enable quantification of the environmental impact of cloud computing;
- Developing energy-efficient and CO_2 aware cloud sourcing and application deployment strategies.
- Testing and evaluating the above innovations with the help challenging case studies

In this issue:

ECO$_2$Clouds benefits the most important stakeholder: the environment.

Even though our project is modest in scope and budget, we believe that small steps can make an impact on the industry. We are not satisfied only by helping IT operations use less energy, more efficiently, and therefore, optimizing and saving significant business operational costs. We have built ECO2Clouds technologies with the objective to build an approach that helps the world be greener.

We have worked during the last two years to build something that matters, that could help organizations implement solutions to help businesses become more sustainable and embrace the “We Are Going Green”, marketing or social corporate responsibility driven trend, by aligning IT operations with sustainability goals according to the increasing demand to provide transparency and build positive corporate social responsibility credentials.

We identify the value of ECO$_2$Clouds in that:

- ECO$_2$Clouds enables **ECO-Monitoring** that extends traditional approach to consider eco-related issues at site, cloud infrastructure and cloud application level.
- ECO$_2$Clouds enables **ECO-Accounting,** based on ECO-Monitoring, providing the means to track energy footprint, impact, optimization and usage; this approach also allows passing collected data along the value chain.
- ECO$_2$Clouds framework provides **ECO-Agility** by adopting ECO-Metrics into the decision making process for deployment and runtime adaptation, in conjunction with new methods and models proposed by our technology that optimize cloud deployments and runtime adaptation.
- ECO$_2$Clouds also enables **ECO-Control** at application level, so cloud applications can also be aware and evaluate their execution performance against ECO conditions and implement actions to take control and to decide their best execution venue.
- These altogether offer greener scenarios in Multi-Cloud environments, which provides yet a more powerful tool for organizations and cloud datacenters, **ECO-Portability** among different sites if using different locations managed by Multi-Cloud software to take advantage of different workload and energy mixes.

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The ECO$_2$Clouds emphasis on CO_2 footprint and environmental impact is what distinguishes our approach from other energy and datacenter resource optimization approaches.

The ECO$_2$Clouds solution includes components for monitoring energy consumption and CO_2 emissions that are used for adapting the site, virtualization infrastructures and application deployments to reduce the CO_2 footprint and to achieve energy efficiency.

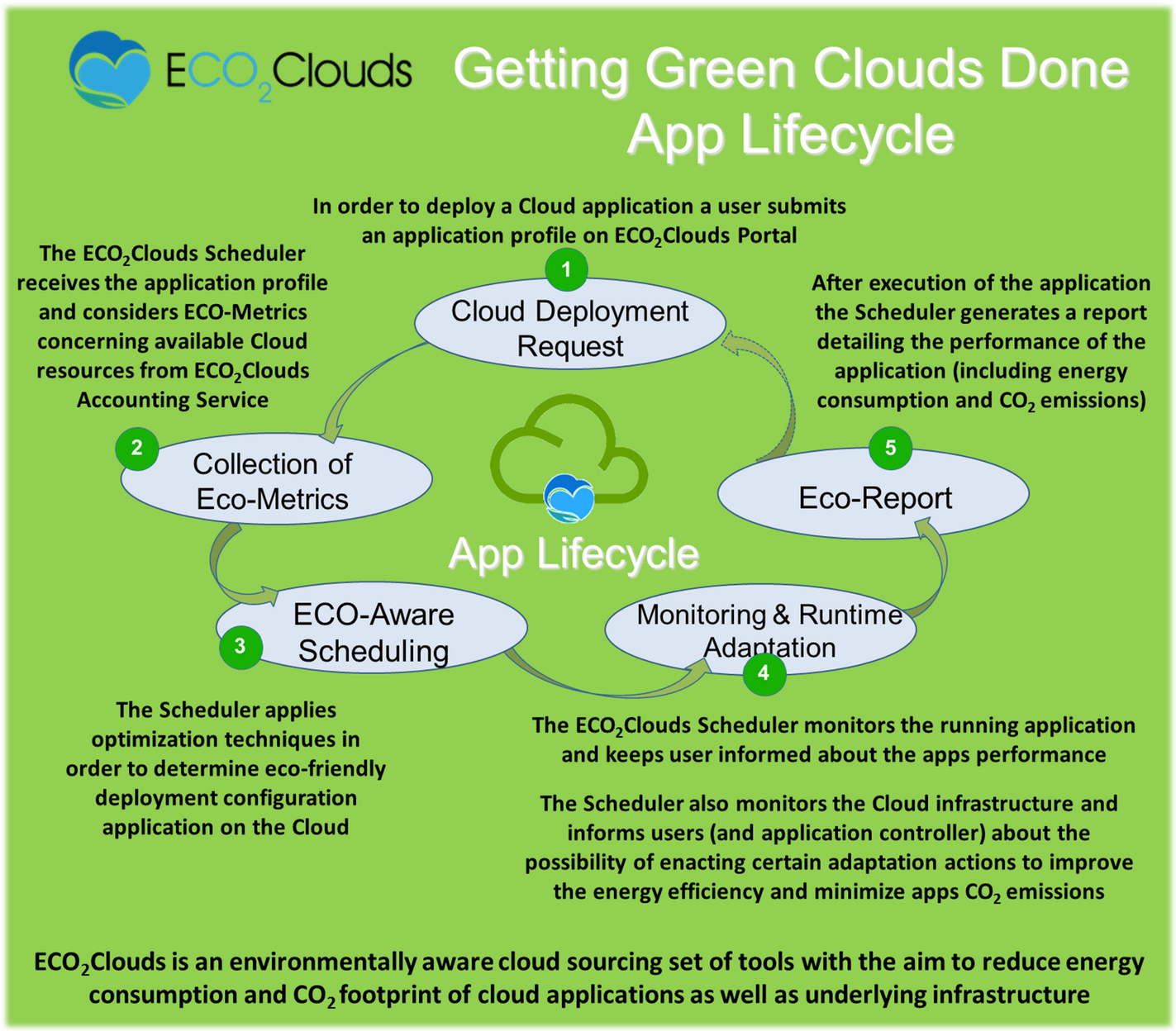
ECO$_2$Clouds Approach

ECO2Clouds is not only about technology

The ECO$_2$Clouds solution is built in a three step approach **"Getting Green Clouds Done" :**

1. Measurement: First put in place the means for quantifying the environmental impact of cloud computing by using a set of metrics that measure the greenness of running applications and infrastructures on sites. This is done with ECO-aware metrics defined by the project. This is a set of metrics that reflects the energy efficiency of IT systems from a holistic perspective and allows the derivation of the interrelation between different components of the IT cloud infrastructure.

2. Monitoring and Analysis: Once the ECO$_2$Clouds metrics and monitoring system are implemented the ECO$_2$Clouds environment is able to collect and track energy and carbon footprint data from sites, physical and virtual infrastructure, and from applications. All gathered data is then fed into an optimization and deployment model and are analyzed to generate application deployment configurations that can contribute towards reducing the environmental impact when the workload is mapped to the infrastructure and VM levels.



3. Acting Green: ECO$_2$Clouds technology allows Acting Green in Cloud infrastructures and software development by employing techniques and mechanisms that consider environmental factors to deploy and manage workloads on multi-cloud scenarios in a greener way. Application self-adaptation possibilities are also considered by using the ECO$_2$Clouds Application Controller.

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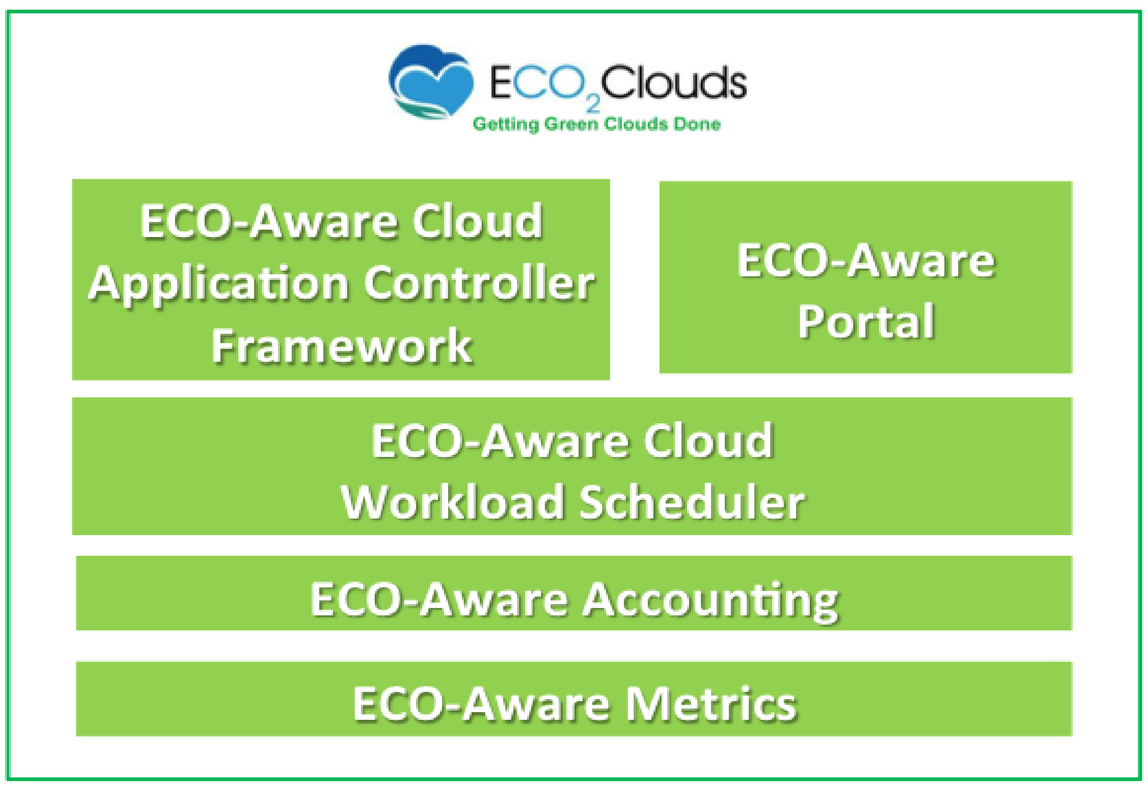
ECO$_2$Clouds ECO-Aware Results

We have worked during the last two years to create the following main outcomes of ECO$_2$Clouds:

- The set of **ECO-Aware Metrics is the underpinning pillar** that provides the quantification of energy consumption and environmental impact according to ECO$_2$Clouds. All other assets rely on these metrics as the baseline to operate. ECO$_2$Clouds considers the following layers: **Infrastructure metrics** includes: the host layer; and the site layer; **metrics at the virtualization layer** characterize the virtual machines on which the applications are running; and **application layer metrics** capture the behavior, in terms of energy consumption and CO_2 emission, of the applications running on the VMs deployed in the infrastructure.
- The **ECO$_2$Clouds ECO-Aware Accounting** is a core asset that is responsible for the monitoring and analyzing ECO-Aware metrics feeds from the underlying cloud and for providing data models the ECO-aware Scheduler and Application Controller. The Accounting component relies on a **REST Metrics API Abstraction** that provides a generic API for retrieving a constant stream of raw values of metrics from the underlying cloud infrastructure monitoring system used. This mechanism assures that the metrics collection works independently from the monitoring infrastructure used for the cloud.
- The **ECO$_2$Clouds Portal**, a user interface intended to act as the entry point for the use and configuration of **ECO-Aware Cloud Scheduling System** and as interaction channel with the user for reporting and notification of cloud infrastructure utilization and status.
- the **ECO-Aware Multi-Cloud Solutions** capable of minimizing CO_2 emissions and optimizing energy efficiency of cloud applications running on federated cloud infrastructures. It provides optimization for initial deployment and then for runtime adaptation at Virtual Machine and application level, as follows:
  - the **ECO-Aware Cloud Workload Scheduler** operates at design-time with the decision about the initial deployment of applications into virtual machines
  - the **ECO-Aware Cloud Application Controller** enables the means to provide ECO-Aware informed runtime adaptation actions at application level.



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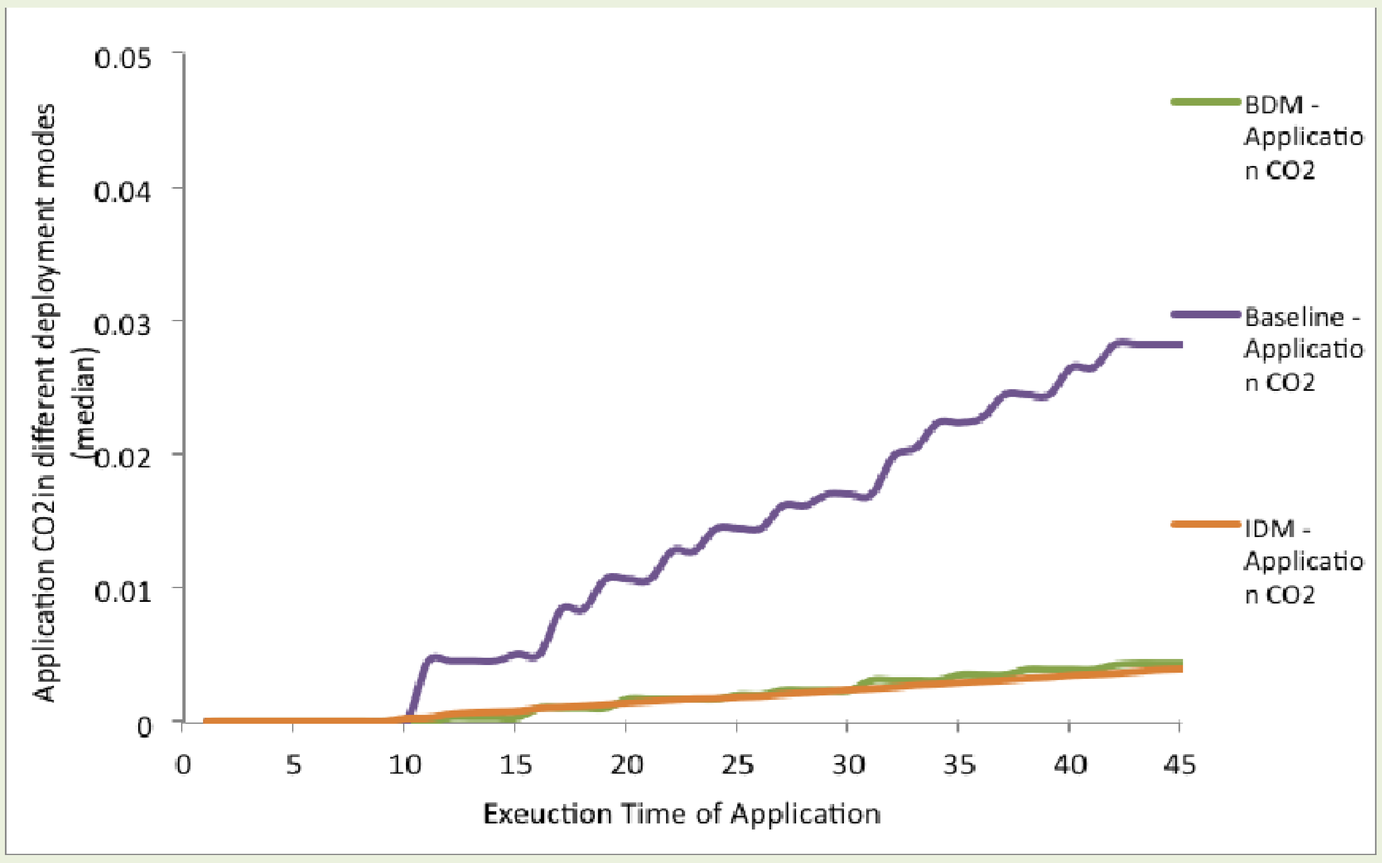
Key Results I - ECO$_2$Clouds at work

To study the behaviour of ECO$_2$Clouds components experimentation was conducted using ECO$_2$Clouds deployment over BonFIRE. The case studies are a mix of HPC and Cloud applications. A further case study, Data Analytics as a Service (DAaaS) was added in the second project period.

Application Deployment or Scheduling

The experimentation to evaluate the effectiveness of eco-aware application deployment VS non-eco-aware or traditional deployment revealed the potential of ECO$_2$Clouds solution to reduce the CO_2 footprint of cloud applications – as shown in the figures below.

Target: Reduce CO_2 footprint of cloud applications



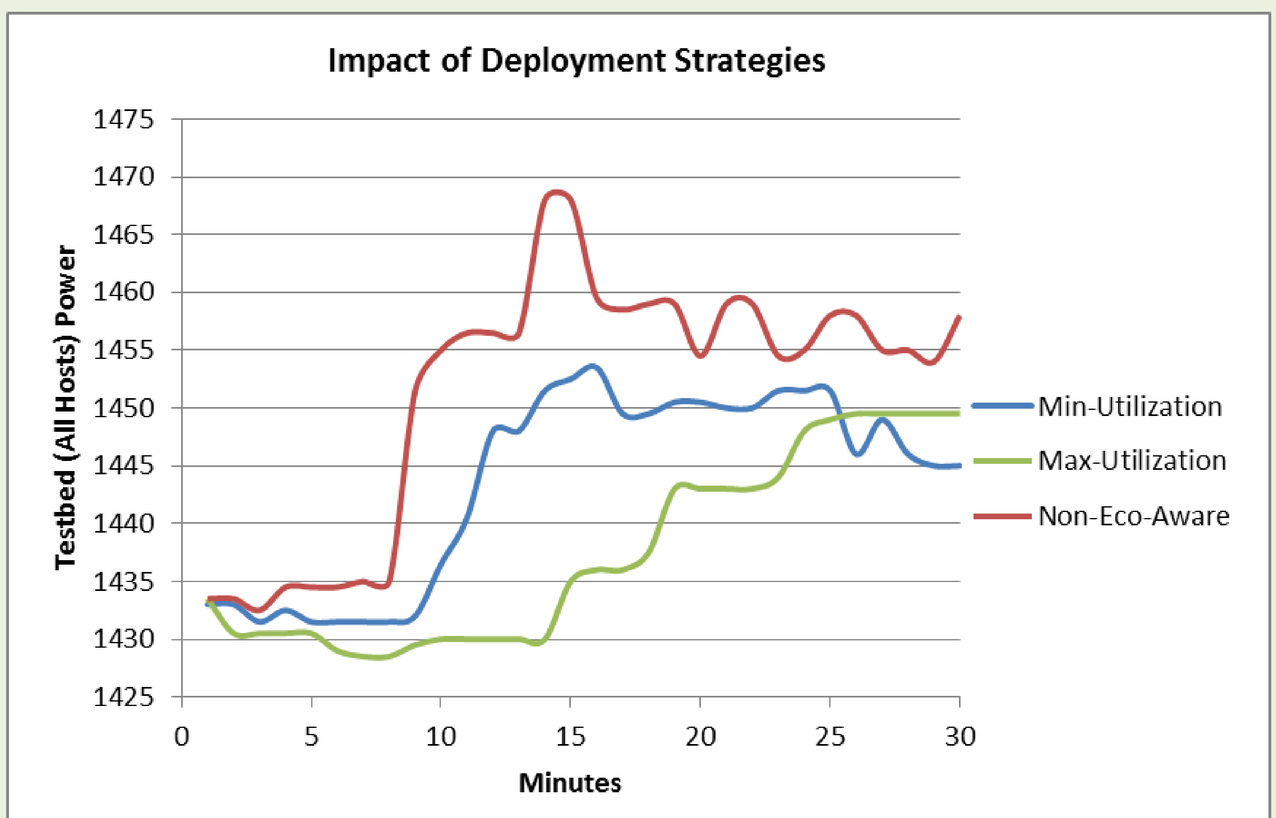
Testbed Selection in a Federated Cloud

BDM: (Bulk Deployment Mode)
An eco-aware strategy for testbed selection in the cloud federation.

IDM: (Individual Deployment Mode)
An eco-aware strategy for testbed selection in the cloud federation.

Baseline: Non-eco-aware strategy that performs random testbed selection in cloud federation

Target: Reduce Energy Consumption of a Testbed



Min-Utilization: Tries to distribute load evenly on available physical hosts or servers after considering a mix of host level eco-parameters

Max-Utilization: Tries to consolidate the application in fewer hosts after considering a mix of host level eco-parameters

Non-Eco-Aware: Allocates load after considering only resource availability parameters of physical hosts.

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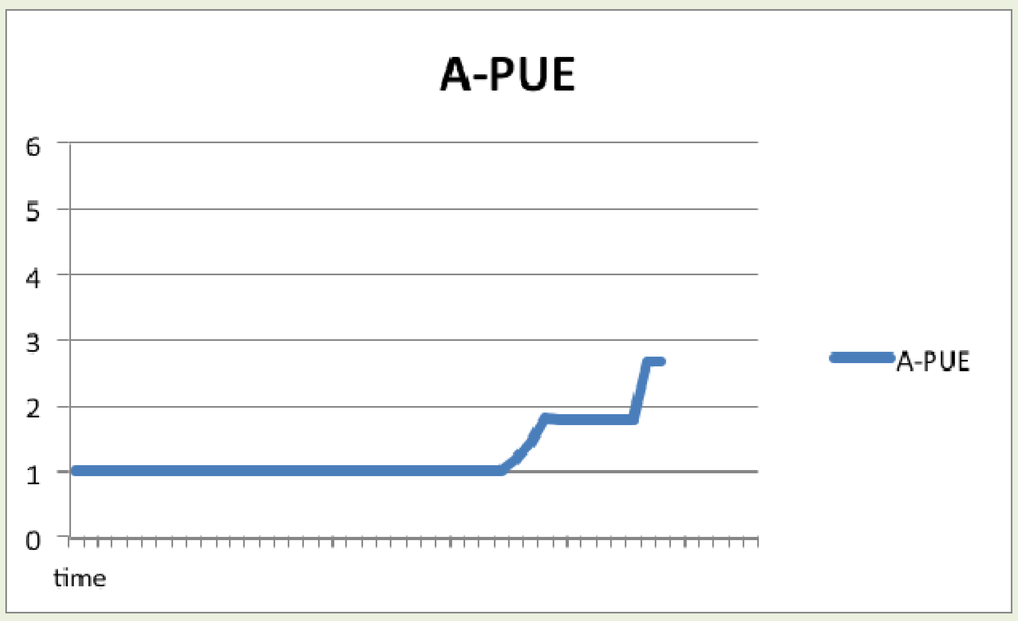
Key Results II - ECO$_2$Clouds at work

Application Deployment Adaptation

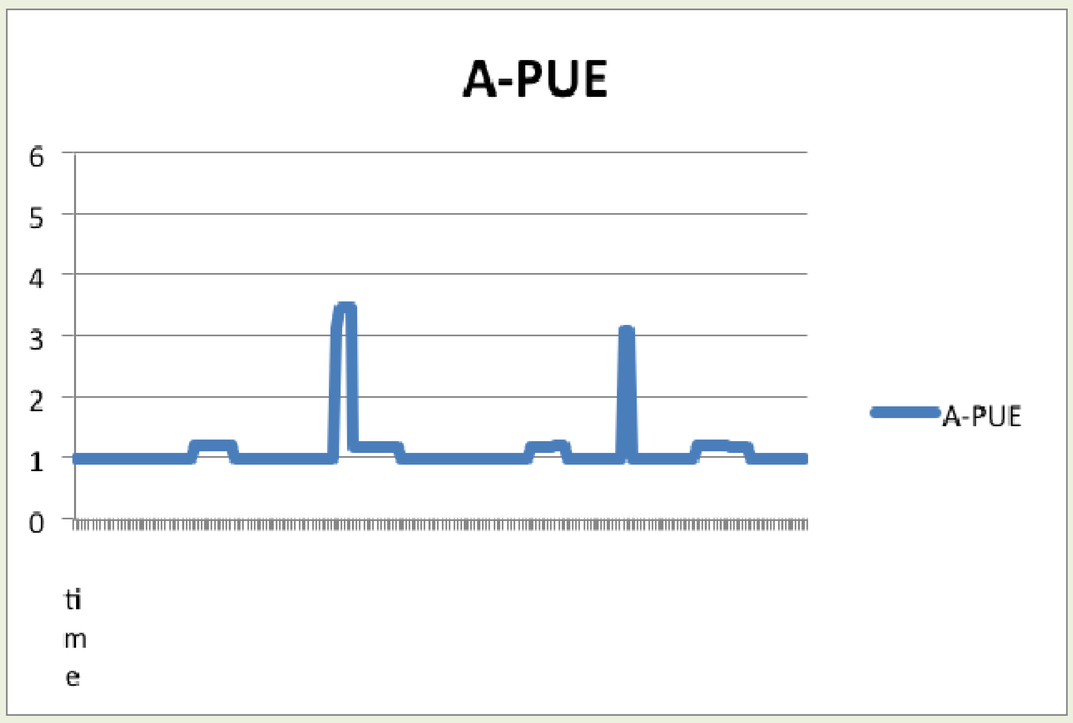
Once the applications are deployed in the cloud infrastructure using eco-aware deployment strategies their deployment configuration can be adapted to further reduce their environmental implications. The adaptation actions can have an impact on various application level metrics such as A-PUE.
The adaptation actions prescribed by ECO$_2$Clouds solutions are:



A-PUE is a good indicator to figure out wastage of energy is occurring at application level.

- Changing load distribution between the active VMs: this action changes the workload among the VMs aiming to have a positive effect on the VM performance e.g. reduction in energy consumption
- Turning off a VM: if a VM is no longer required it can be stopped to reduce energy consumption and CO_2 footprint of application
- Application execution time-shifting: this action aims to reduce the CO_2 emissions by running the application or part of it at a time when there is more green energy available in the testbed.

The reduction of CO_2 emissions can be achieved by focusing on workload distribution within the application.
In other words, a good application design can itself help reduce environmental implications of cloud computing



Affects of adaptation actions (e.g. switching off a VM that is no longer used by application) on A-PUE

A-PUE is inspired from the most comment PUE metrics defined for the Datacenters to compute the ratios between the energy consumed by the VMs and the actual energy used to run the application in the VMs.
The figure shows an example of the influence of adaptation actions on the A-PUE trend. Here the effects of adaptation i.e. switching off the no longer used VMs is clear. The spike in the A-PUE corresponds to the termination of one of the application specific tasks and as the VM starts computing the work initially assigned to another task the power consumed by this VM is no longer wasted

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Lessons Learnt and Future Potential

Where do we stand now ?

In terms of new developments, distributed resource utilization and ease of access enabled by cloud computing is a step forward from traditional networking topologies and grid. This new connectivity and access model allow investigation of new ideas and techniques for service delivery while considering different aspects like energy efficiency, efficiency, cost savings and other aspects. However, based on the low levels of awareness about environmental implications, lack of standardization and best practices, the *commercial drive* for eco-friendliness is currently not there to realize full commercialization potential of energy efficiency systems at large. In this respect, establishment of *new regulatory and standardization measures* and code of conduct can be an important step.

Drivers for environmentally aware cloud computing: cost, efficiency or environmental concerns?

The reasons for energy efficiency can be different at the developer (of technological solutions) level and at the organization level. At the organization level, cost is the most important factor or motive for achieving energy efficiency, and environmental concerns can follow from that. On the other hand, for technology developers, efficiency is the top priority and can consequently translate into energy saving and other benefits. However, sometimes, less emphasis can be placed on efficiency in favor of quality assurance. Environmental aspects are currently only limited to partial sectors of society and therefore depend on individual commitments or on enforcement by regulatory authorities.

Following we provide a summary of discussions that place during the Energy Efficient Systems Workshop at ICT4S conference in Stockholm (August, 2014)

ECO2Clouds – New Ideas and Future Potential

This topic was raised to gather general opinions about ECO$_2$Clouds based on the key aspects of the project, particularly the CO_2 measurements at different levels of the cloud infrastructure and using such information in the application deployment and adaptation decision making.

The new idea developed in ECO$_2$Clouds is *the awareness of energy mix and its utilization in the decision making model and control mechanisms*. In terms of future potential of ECO$_2$Clouds ideas, there are various issues that can hold back any technological advancements in the area of energy efficiency. These include varying level of support and regulatory measures concerning CO_2 emissions e.g. dynamic energy mix information is not available in Germany and in France the regulations are in place for CO_2 audit of companies but there are no penalties yet. However, the advancements made in the project can be seen as a step in the right direction.

Research in the area of energy efficiency is making its way towards mainstream technologies and is influencing different sectors of industrial solutions. E.g. some cloud service providers are pitching the use of green energy sources as their main marketing messages. However, further research, standardization and clarity of existing regulatory measures can help boost the awareness about energy efficient solutions and ensure transparency across different levels of the market.

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Spreading the word about ECO$_2$Clouds

General papers about energy efficiency, and environmental impact

- Pernici B. (Politecnico di Milano, Italy) and Wajid U. (University of Manchester, UK). Assessment of the environmental impact of applications in federated clouds. *SmartGreens 2014*, Barcelona, April 2014

- Cappiello C., Melià P., Pernici B., Plebani P. and Vitali M., Sustainable choices for cloud applications: a focus on CO2 emissions, *International Conference on ICT for Sustainability (ICT4S),* Stockholm, Aug. 2014

- Vitali M. and Pernici B. (Politecnico di Milano, Italy). A survey on energy efficiency in information systems. *International Journal on Cooperative Information Systems*, March 2014

- Wajid U., Pernici B., Francis G. Energy Efficient and CO2 Aware Cloud Computing: Requirements and Case Study. *Special Session at IEEE International Conference on Systems, Man and Cybernetics (SMC*). October 14, 2013, Manchester, UK

Papers about monitoring ecometrics

- Tenschert A., Skvortsov P. and Gienger M. "Eco-efficient Cloud Resource Monitoring and Analysis", *Energy-efficient systems workshop at ICT4S*, Stockholm, Aug. 27, 2014

- Cappiello C., Pernici B., Plebani P. and Vitali M.. "Eco-reports in Clouds", *Energy-efficient systems workshop at ICT4S*, Stockholm, Aug. 27, 2014

Papers about eco-aware control mechanisms

- Gribaudo M., Ho N.T.T, Pernici B., Serazzi G. Analysing the influence of application deployment to energy consumption, *E2DC*, Cambridge, June 2014

Events

- Workshop on Energy Efficient Systems at International Conference on ICT for Sustainability (ICT4S) – Stockholm, August 2014
  http://eco2clouds.eu/news-and-events/workshop-on-energy-efficient-systems-at-ict4s/

- ECO$_2$Clouds participation in the SeaClouds Workshop (colocated with ESOCC 2014) – Manchester September 2014 http://seaclouds.icc.uma.es

Energy Efficient Systems Workshop was organised by ECO$_2$Clouds at ICT4S conference in Stockholm (Aug, 2014)

ECO$_2$Clouds in the Press

ECO$_2$Clouds appears in the next issue of IAM Innovator magazine (innovator.eai.eu) dedicated in multi-cloud as a innovative approach towards taking green action in cloud computing.

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Consortium and contact information

ATOS, Spain

Atos is an international company focused on Services for Information Technologies (IT) and currently with headquarters located in Paris, with presence in 42 countries.

University of Manchester, UK

The University of Manchester (UNIMAN) is the largest campus based university in UK with close links to industry.

HLRS, Germany

The High Performance Computing Center is a research and service institution affiliated to the University of Stuttgart. It has been the first national supercomputing center in Germany offering services to academic users and industry.

EPCC, UK

EPCC is the High-Performance and Novel Computing Centre of University of Edinburgh. EPCC provides a wide variety of services to academia and industry.

Politecnico di Milano, Italy

Politecnico di Milano is a State University in Italy, established in 1863, ranked as one of the most outstanding European universities.

Inria, France

Inria is the only public research body fully dedicated to computational sciences. Inria collaborates with the main players in public and private research in France and abroad.

ECO$_2$Clouds
Advancing ecological awareness in the Cloud

Identifying good practices to improve energy efficiency of Cloud data centers
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Developing techniques and mechanisms for CO2 aware application deployment on Cloud

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ECO$_2$Clouds results are available as Open Source in ECO$_2$Clouds.com

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