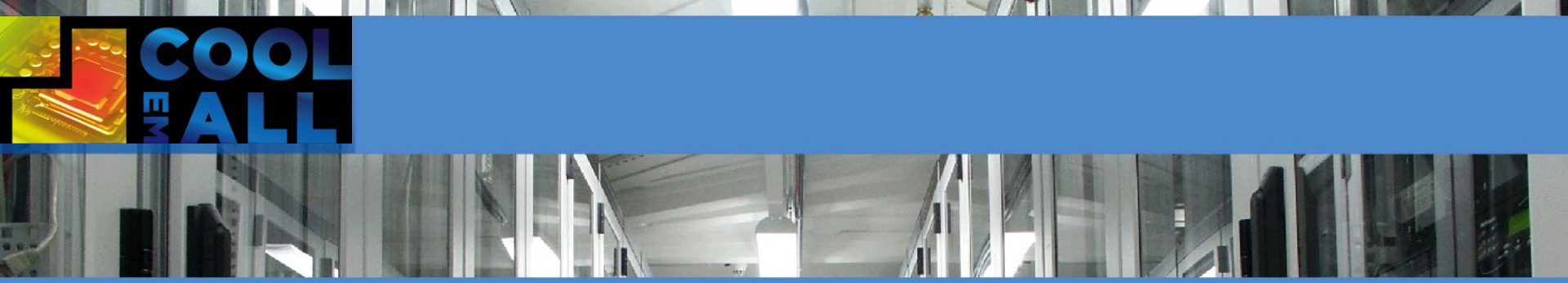

CoolEmAll

Optimizing cooling and energy efficiency in Data Centers

A holistic approach

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[2] High Performance Computing Center Stuttgart (HLRS)

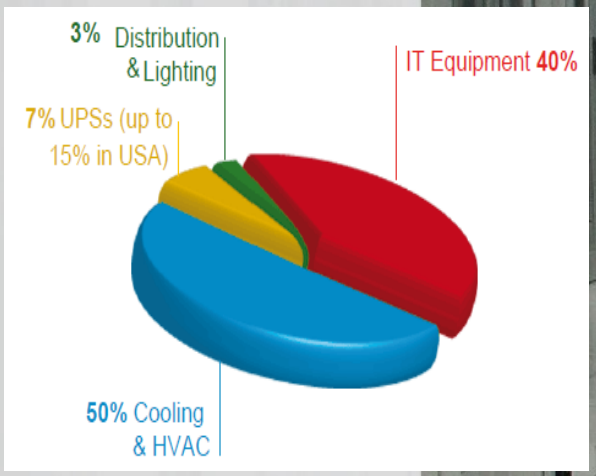
[3] Poznan Supercomputing and Networking Center (PSNC)

Outline

- Introduction
- CoolEmAll project
- DEBBs
  (Data centre Efficiency Building Blocks)
- SVD Toolkit
  (Simulation, Visualization and Decision support toolkit)
- Optimizing cooling efficiency
- Summary

Introduction

- Situation today:
  - ICT sector is responsible for around 2 % of the global energy consumption, data centres taking large fraction of it
  - **Energy consumption in a data centre:**
    - Result of executing workload (user jobs) on (HPC/Cloud) resources
    - Energy consumptions depends on:
      - workload (jobs) and application type (nature of jobs)
      - Efficiency of HW / resource
      - Resource management strategy
      - Cooling efficiency (depends on environmental conditions, heat load and arrangement of racks)
  - In many data centres, **50 % of the energy is consumed by cooling** (resulting in bad energy efficiency)



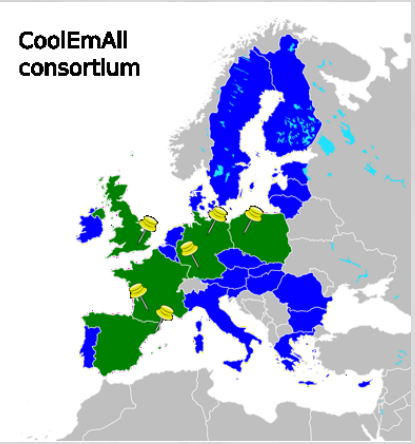
→**potential for improvement, addressed in CoolEmAll project**

What is all about?

COOLEMALL PROJECT

CoolEmAll Project

- FP7 ICT Call 7
- Budget: 3614210€ (funded: 2645000€)
- Duration: 30 months
- Start date: 1st Oct 2011
- Web-site: www.coolemall.eu

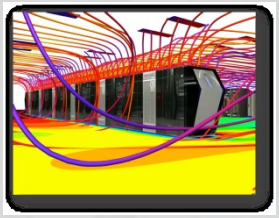


- Consortium

HLRS · POZNAN SUPERCOMPUTING NETWORKING · Atos Origin · the 451 group · IRIT Institut de Recherche en informatique de Toulouse · IREC Institut de Recerca en Energia de Catalunya Catalonia Institute for Energy Research · CHRISTMANN INFORMATIONSTECHNIK + MEDIEN

CoolEmAll Goal

- CoolEmAll EU Project: www.coolemall.eu
- **Goal**:
  evaluate and improve cooling- and energy-efficiency of modular data centers by **optimization** of their **design** and **operation** for a wide range of **workloads, IT equipment** and **cooling options**



- **Main results:**
  - Optimized ComputeBox Blueprints and Data Centre Efficiency Building Blocks (**DEBBs**) reflecting HW and facility-configuration/models used by SVD Toolkit
  - Simulation, visualization and decision support toolkit **(SVD Toolkit)**, enabling optimisation of modular data centre building blocks for a wide range of options

CoolEmAll Approach

Scale

- Server
- Rack(s)
- DC/Container(s)

Density

- High density (up to hundreds nodes in a rack)
- Low density

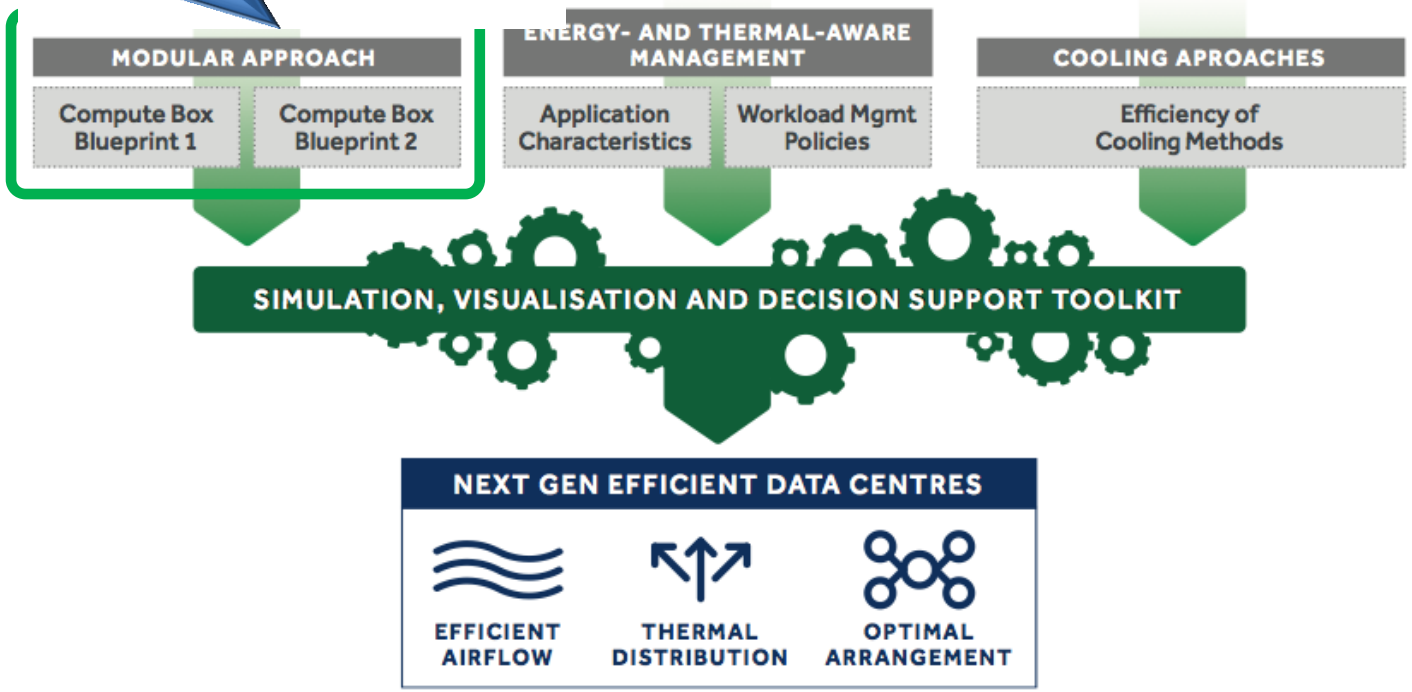
Cooling

- Integrated
- No integrated cooling

Arrangement

- Position

Data Center efficiency Building Blocks (**DEBB**) – models of IT equipment on various scale level



CoolEmAll Approach

Application types

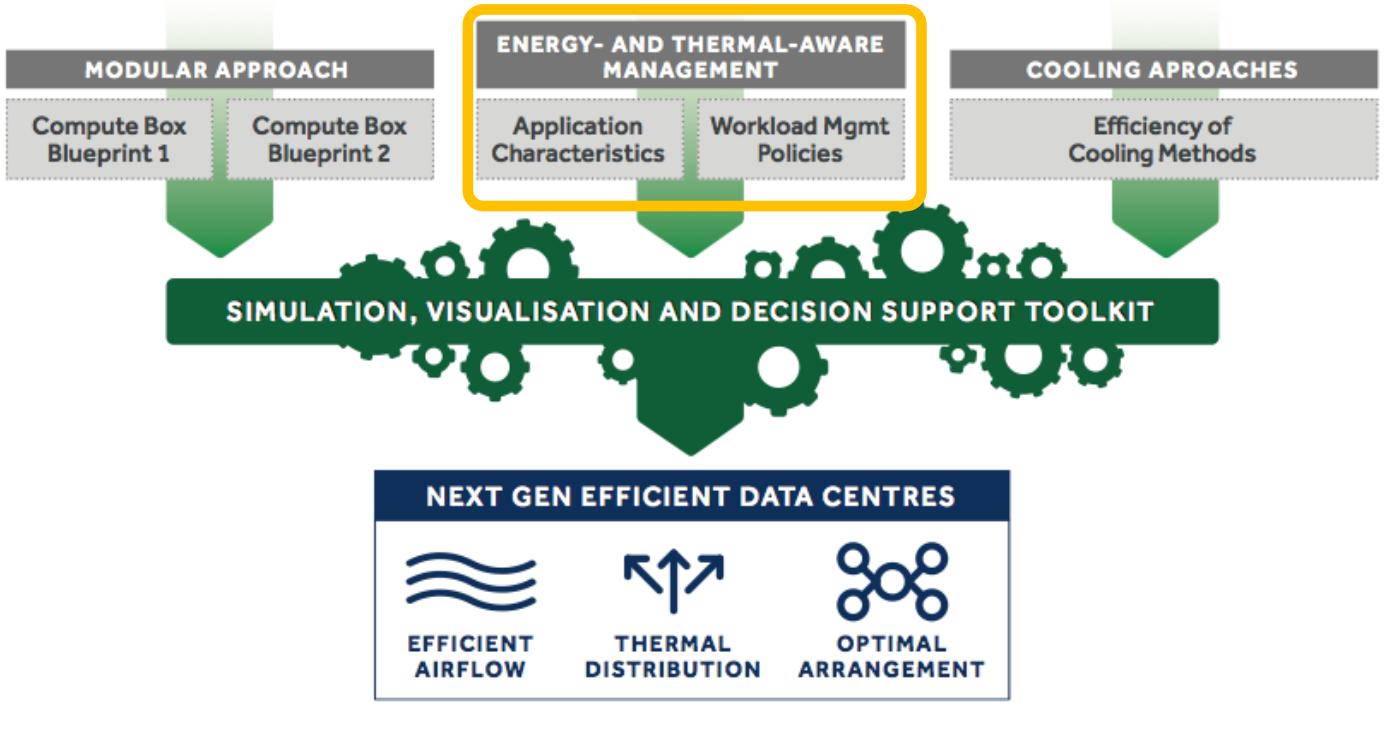
- HPC
- Virtual machines

Application characteristics

- CPU-bound
- Mem-bound
- IO-bound
- Scale

Workload mngmt policies

- Workload consolidation
- Energy-aware policies
- Thermal-aware policies



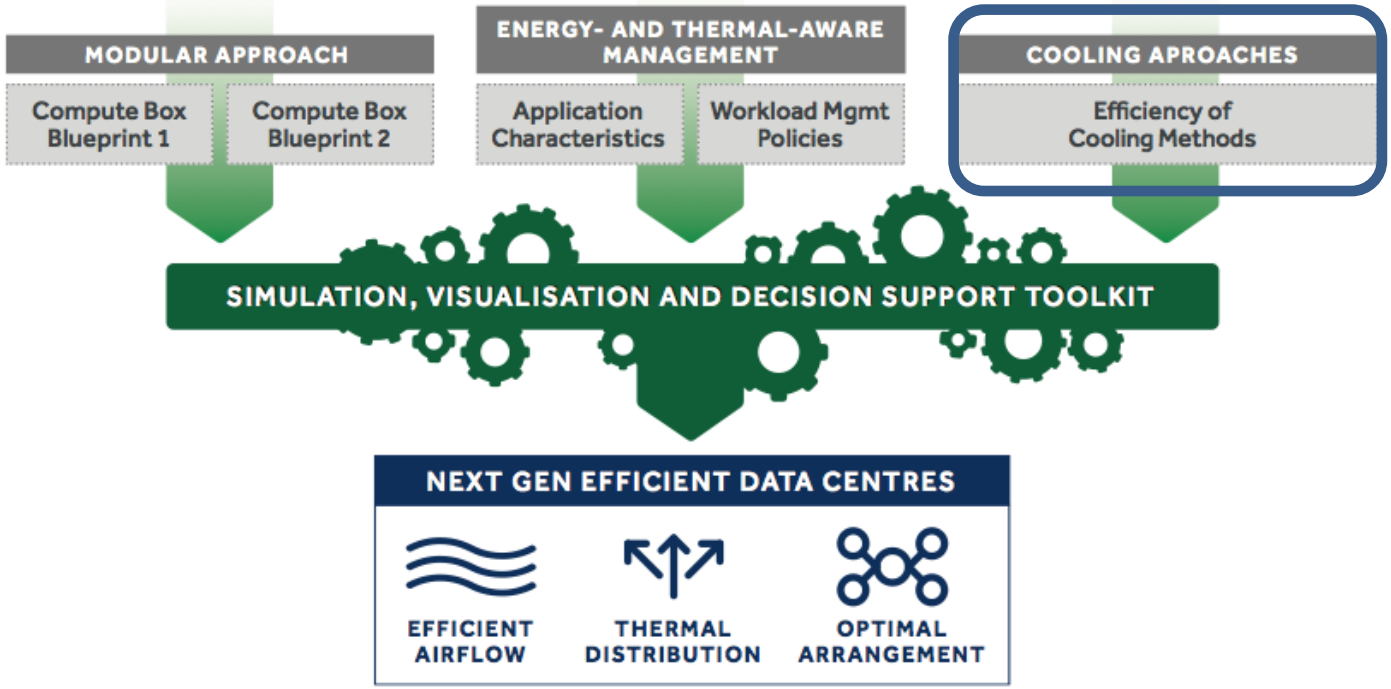
CoolEmAll Approach

Models of Cooling devices

- CRAC, Chillers, fans, heat-exchanger..

Operation params

- Higher server room temperature
- Free air cooling
- Liquid cooling



CoolEmAll Approach

Visualisation

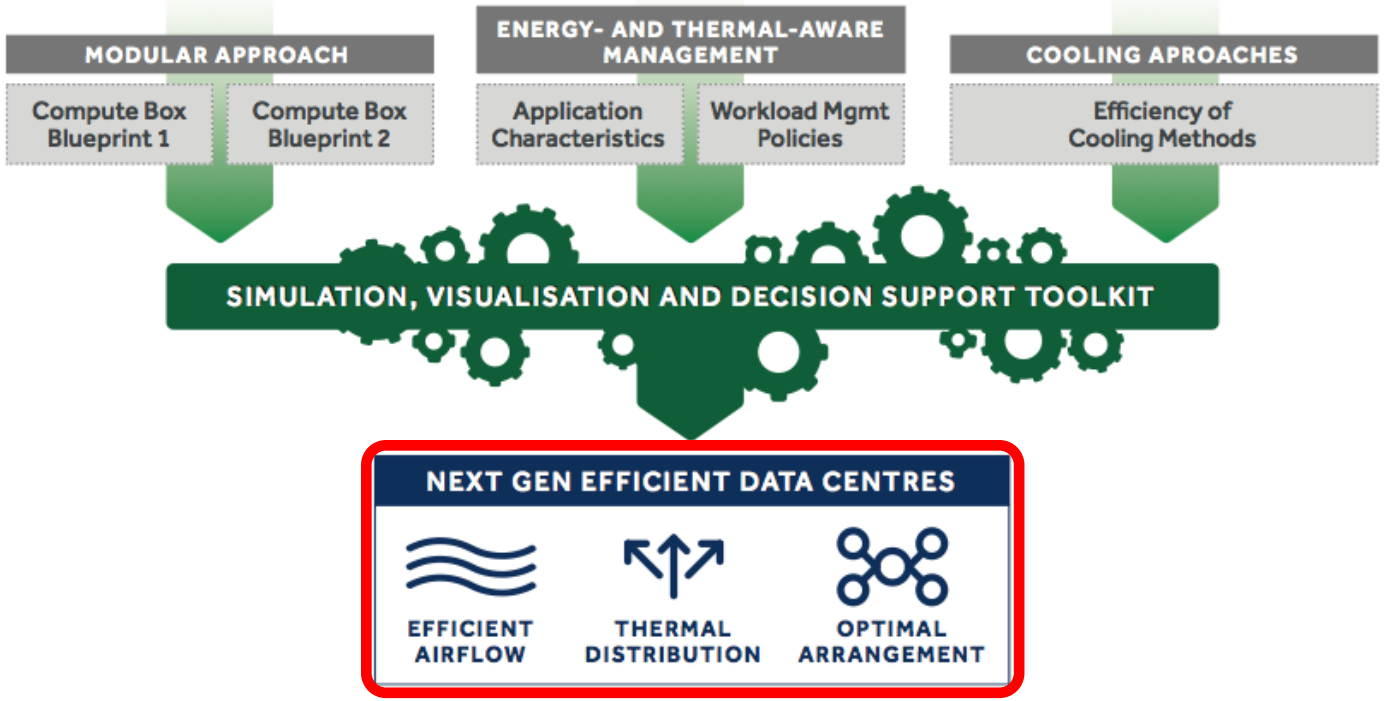
- Air/heat flow distribution map

Evaluation Metrics

- Cooling / Airflow related metrics
- Energy/Power related metrics (PUE)
- Productivity metrics

Interaction

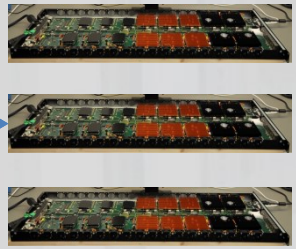
- Rearrangement
- Env. Conditions
- …



ComputeBox & DEBB concepts

DATA CENTRE EFFICIENCY BUILDING BLOCKS (DEBB)

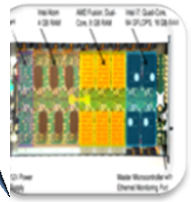
DEBB



- What is a DEBB?
  - **D**ata Center **E**fficiency **B**uilding **B**lock
  - The DEBB is an abstraction for computing and storage hardware and describes energy efficiency of data-center building blocks on different granularity-levels.
- Purpose: To find the most energy efficient configuration while planning a data center
  - Used for thermodynamic modeling (SVD Toolkit)
  - Used for configuration and reconfiguration
- Availability
  - To be publicly available
  - Defined according to open specification

DEBB Specification

Component Description
- CIM naming conventions

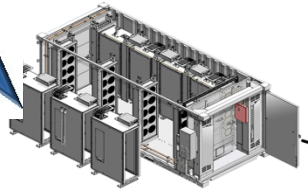


Components Description

Power Profile

Power Profile
- Power-Usage
- Under various loads

Hierarchy
- Hierarchy of building blocks
- PLMXML



Hierarchy with position of objects

DEBB

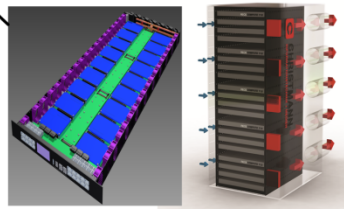
Metrics

Energy efficiency metrics
- Productivity
- Power/energy
- Under various load

Air-flow profile
- Airflow
- Inlets/Outlets
- Under various load

Thermodynamic

Geometry Data for CFD shapes)



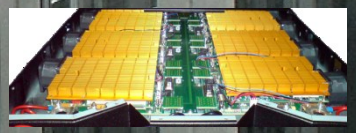
Geometry Data for visualizatio

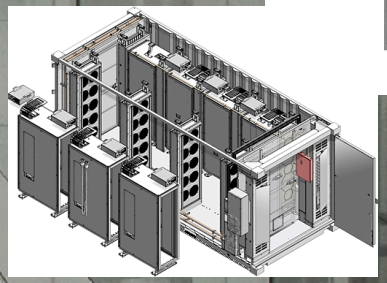
Geometry for CFD
- Simple, STL

Geometry for visualization
- Advanced
- VRML

DEBB Granularity Levels

- Granularity-levels
  - **Node unit**
    single blade CPU unit
    (for instance a RECS CPU module)
  - **Node group**
    assembled unit of node units
    (for instance a complete RECS18)
  - **ComputeBox1**
    reflects a typical rack
  - **ComputeBox2**
    Reflects a container or a Data Centre filled with racks and additional infrastructure

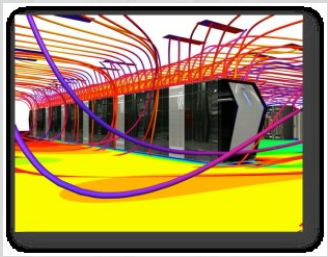




Simulation Visualization and Decision support Toolkit

SVD TOOLKIT

SVD Toolkit



- **SVD-Toolkit** allows analysis and optimisation of modular IT infrastructure built of DEBBs (level n), taking into account (input parameters):
  - HW-Models (represented by DEBBs on level n)
  - Workloads and Application Models
  - Workload- & Resource Management Policies
  - Cooling methods and environmental conditions
- **To be achieved by combining:**
  - Coupled simulations of various workloads and applications,
  - CFD simulation to analyze airflow and heat transfer in a data centres
  - Visualization of results
  - Assessment of Results

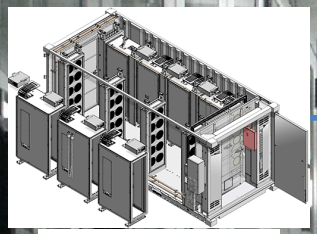
Holistic approach

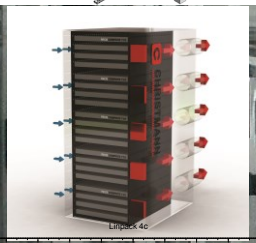
Integrated analysis of workloads, IT equipment, and heat transfer

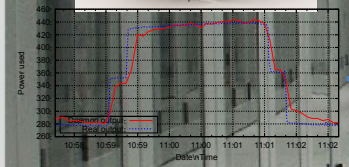
Coupled Simulation

(1) Workload- and HW behavior

(2) Simulation of cooling and heat processes (air + liquid)



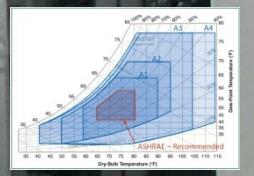


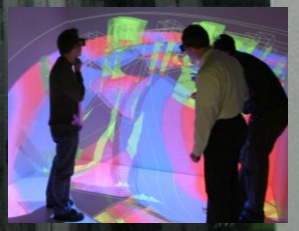


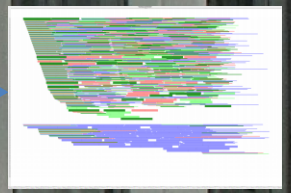
Metrics Calculation

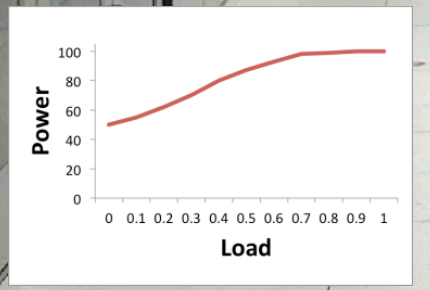
CFD Simulation

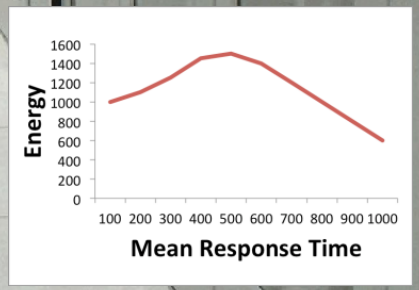
Workload and Resource Simulation







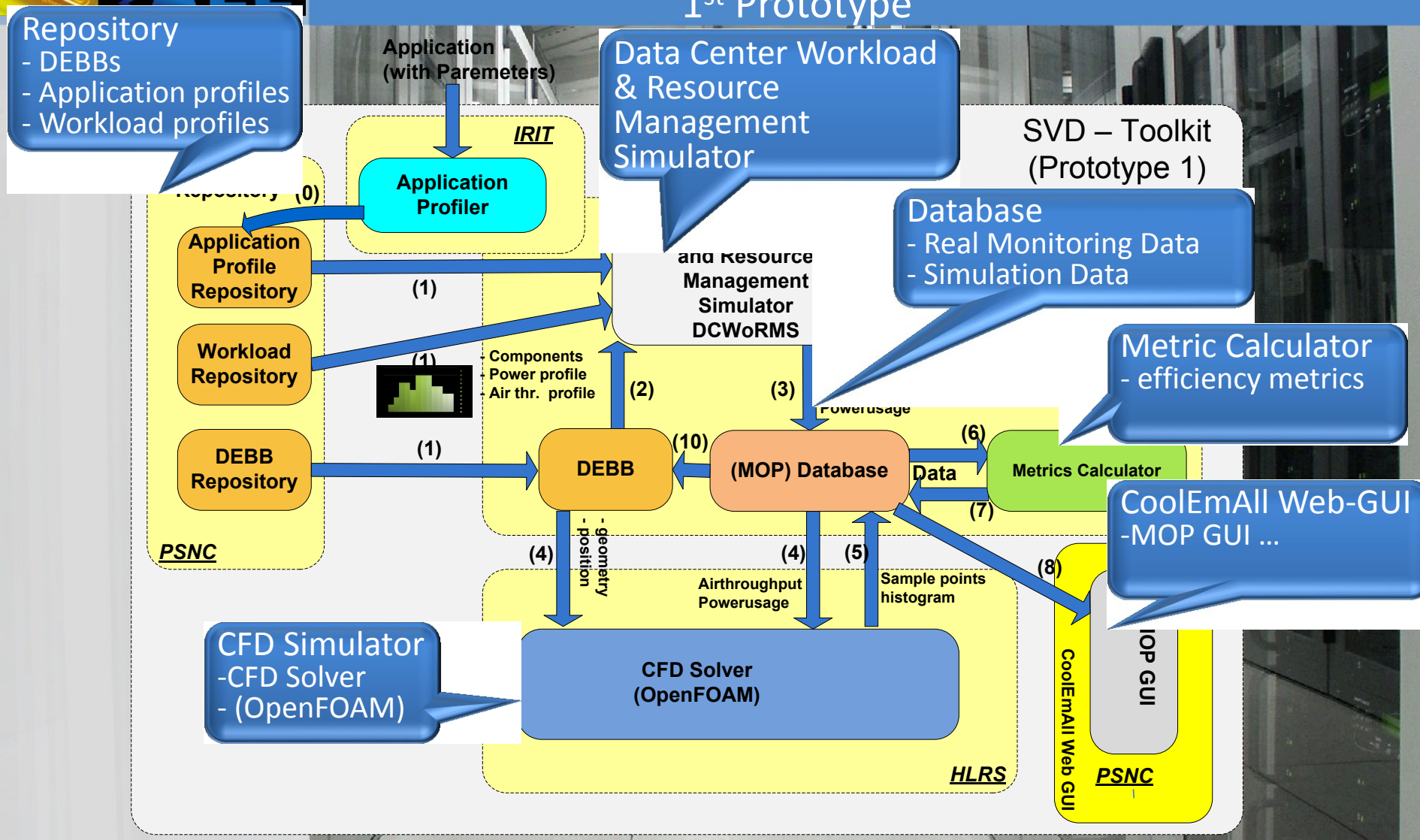




Energy-Efficiency Metrics to assess simulation results

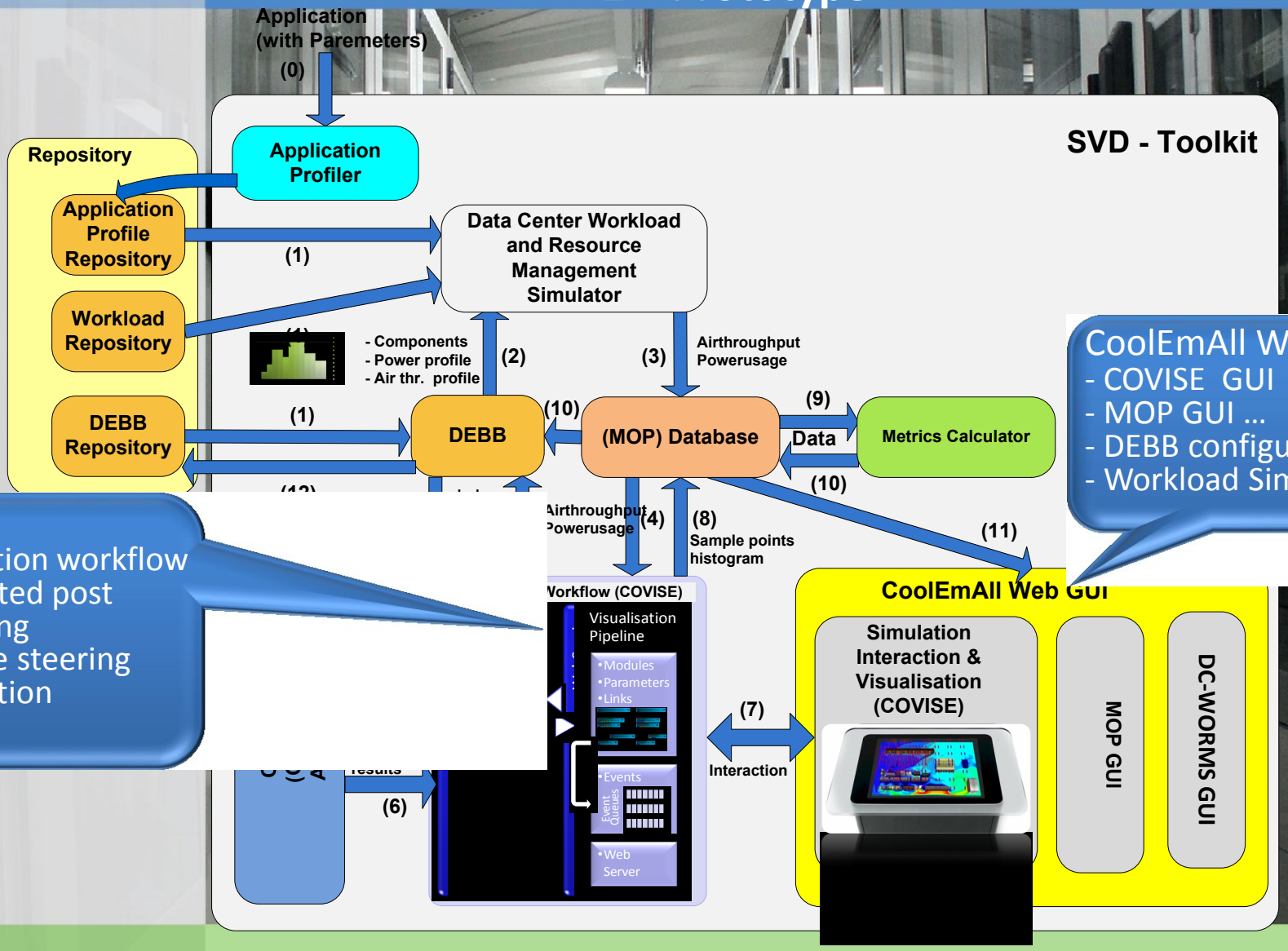
SVD Toolkit Architecture

1st Prototype



SVD Toolkit Architecture

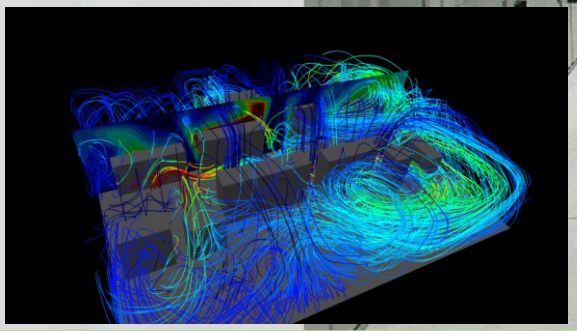
2nd Prototype

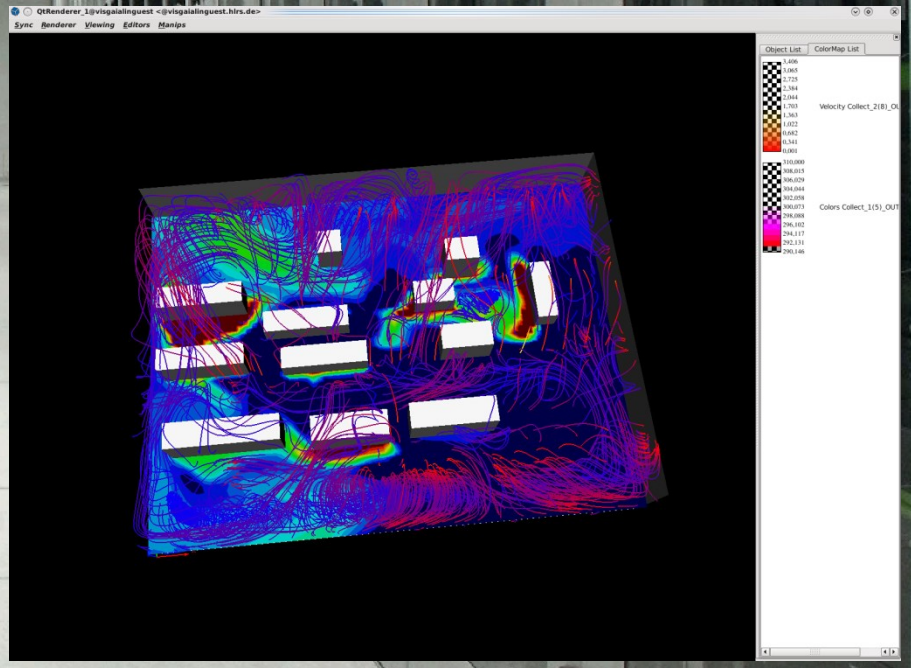


SVD Toolkit 2nd Prototype

2nd Prototype

- CFD Simulation using COVISE and OpenFOAM
- Rack rearrangement in Compute-Room
- interactive simulation
- Remote steering



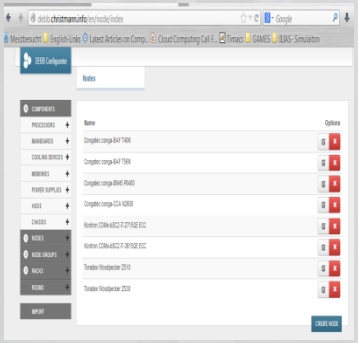


SVD Toolkit 2nd Prototype

- CoolEmAll WEB-GUI – advanced Visualisation Tool
  - Web based GUIs to all components
    - DEBB configurator
    - Selection of Application Profiles, Workloads
    - Workload Selection and Simulation
    - Interactive steering and visualisation
    - …

→ Easy usage of SVD Toolkit

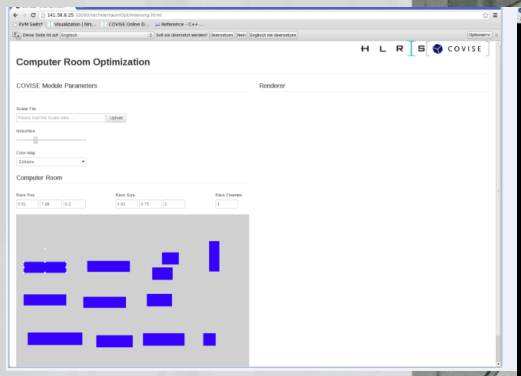
DEBB Configurator



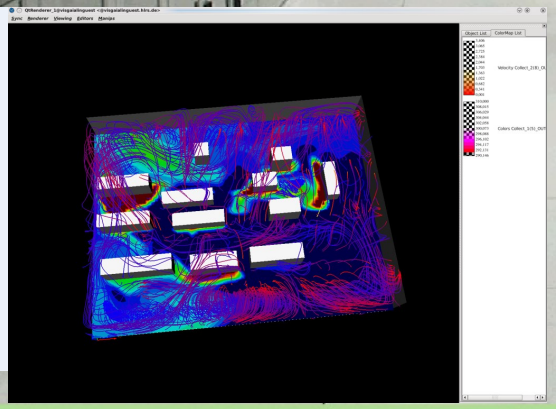
Energy usage

Scheduling

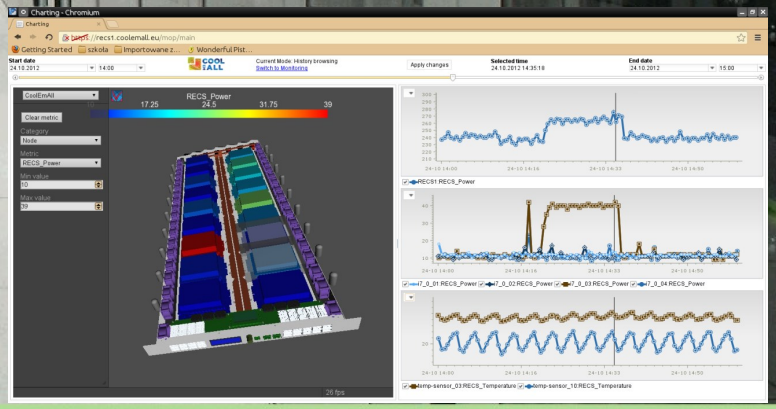
Interactive rack (re)arrangement



COVISE Visualisation



MOP-GUI Visualisation

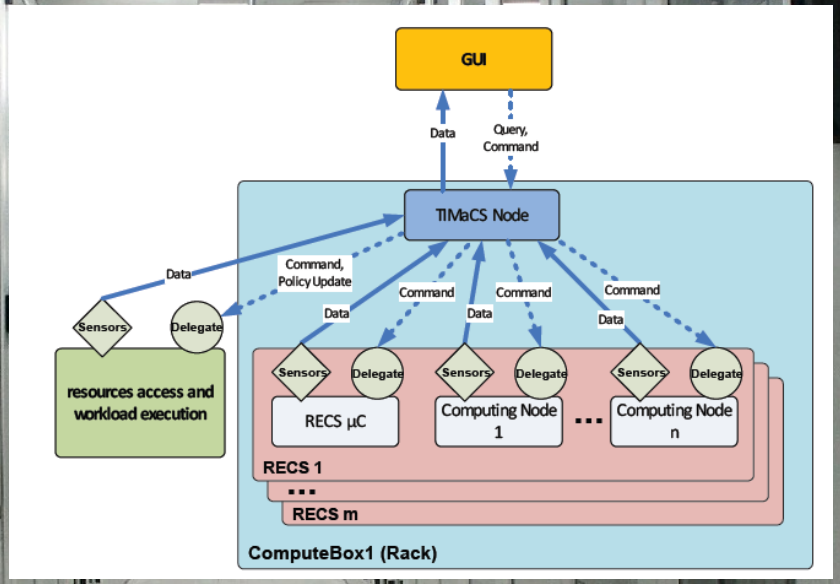


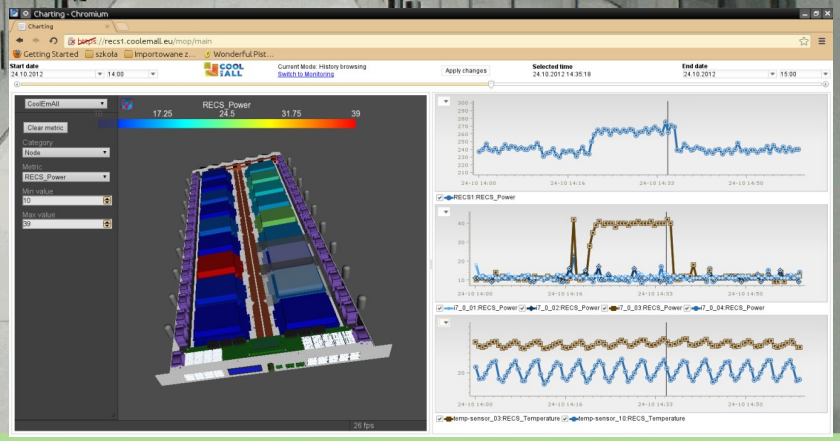
Validation of models

Simulations based on real measurements and re-usable building blocks

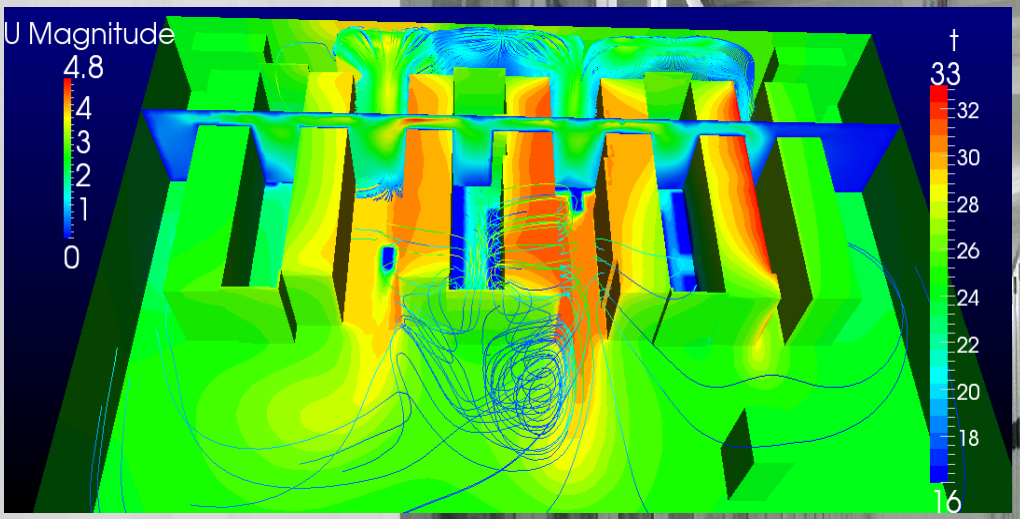
Real monitoring data from execution of experiments on test bed

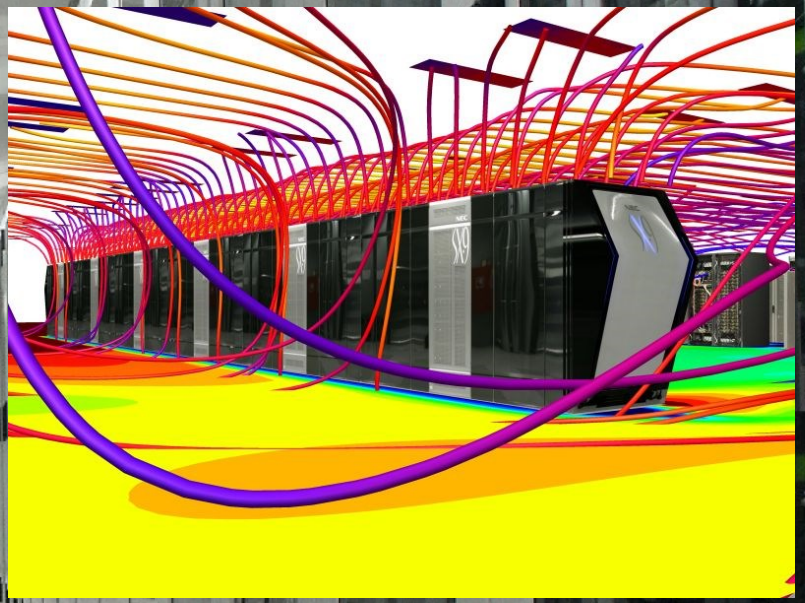
Comparison of real measurements with simulation models

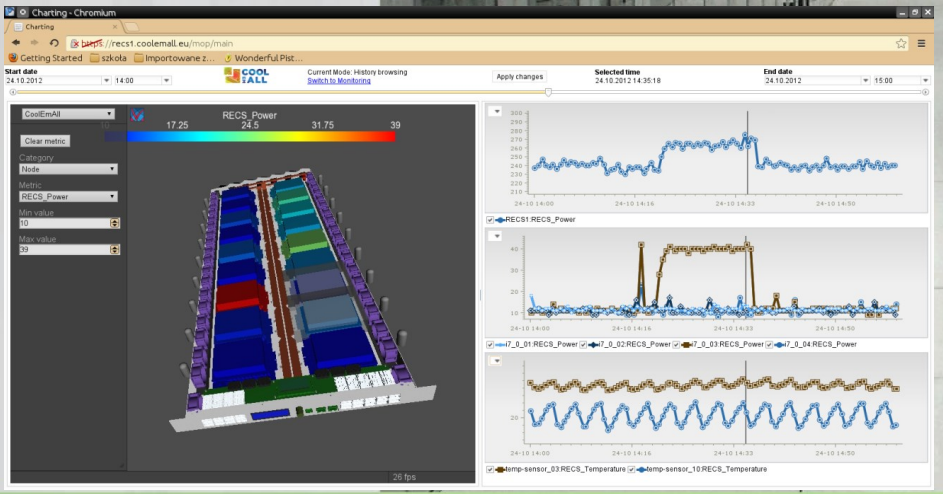




SVD Toolkit Output





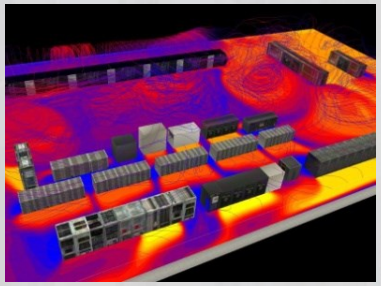


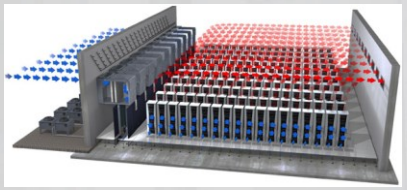
- Virtual thermal camera
- Heat transfer and air flow processes
- Remote, interactive visualization
- Efficiency metrics

What can it be used for?

OPTIMIZING COOLING EFFICIENCY

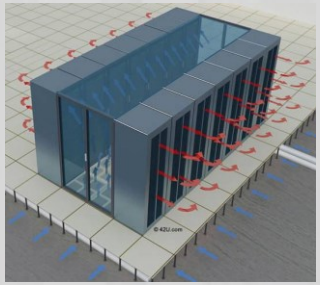
Main Use-Cases

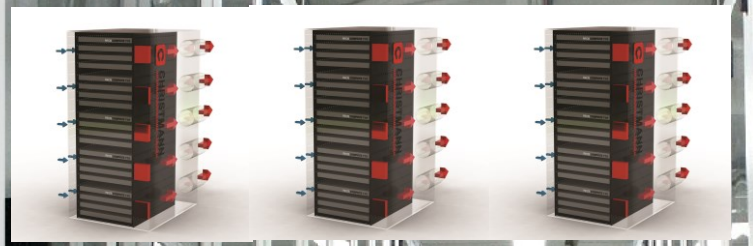


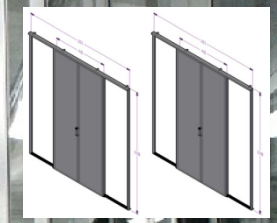


- UC1 - Optimization of rack arrangement in a server room using open data centre building blocks
  - Goal: To find an optimal arrangement of racks and aisles containment to prevent hot and cold air mixing and minimize risk of hot spots.
- UC2 - Capacity management
  - Goal: To select the optimal configuration of hardware and given application types factoring in performance and energy-efficiency constraints
- UC3 - Analysis of free cooling efficiency
  - Goal: To find a maximum inlet temperature in which data centre can operate safely for given workloads

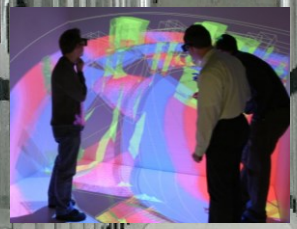
UC1: Optimisation of rack arrangement

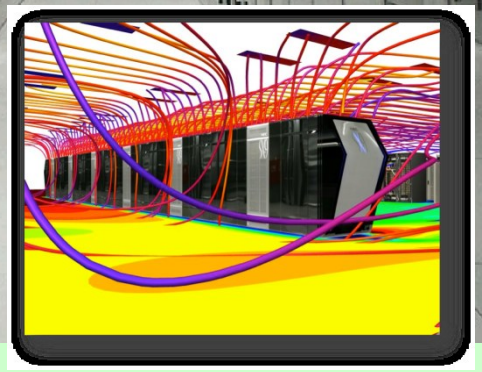






Repository





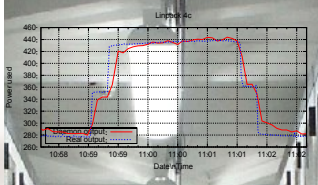
Goal: To find an optimal arrangement of racks and aisles containment

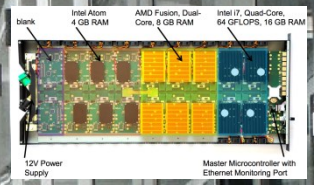
Optimisation of rack arrangement

Video – interactive rearrangement racks in server-room

- Analysis and Visualization of heat flow distribution
- Identification of hotspots
- (see www.coolemall.eu)

UC2: Capacity management





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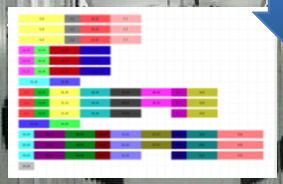
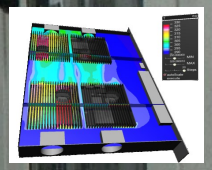
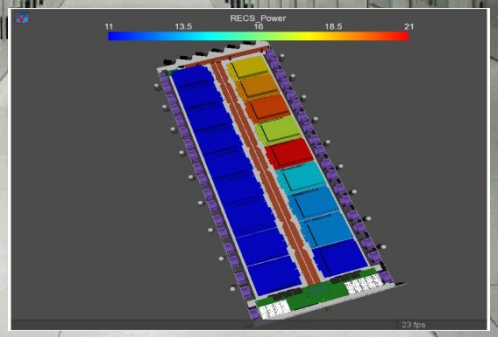
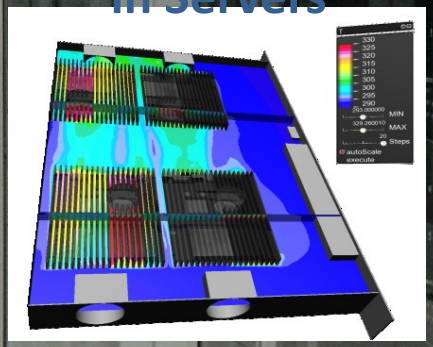






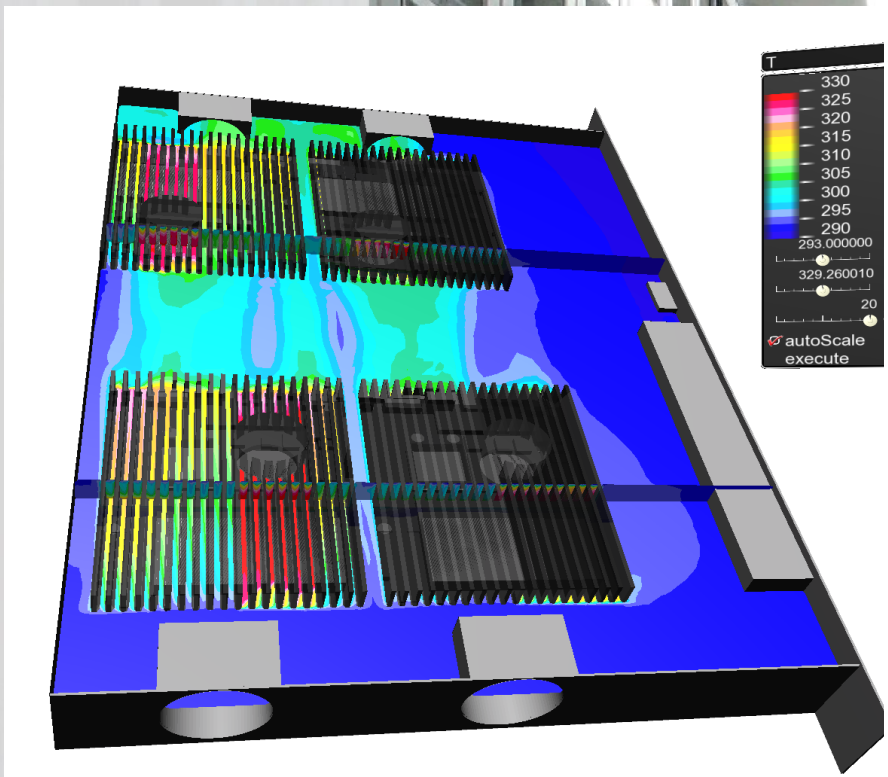
simulating airflow in Servers



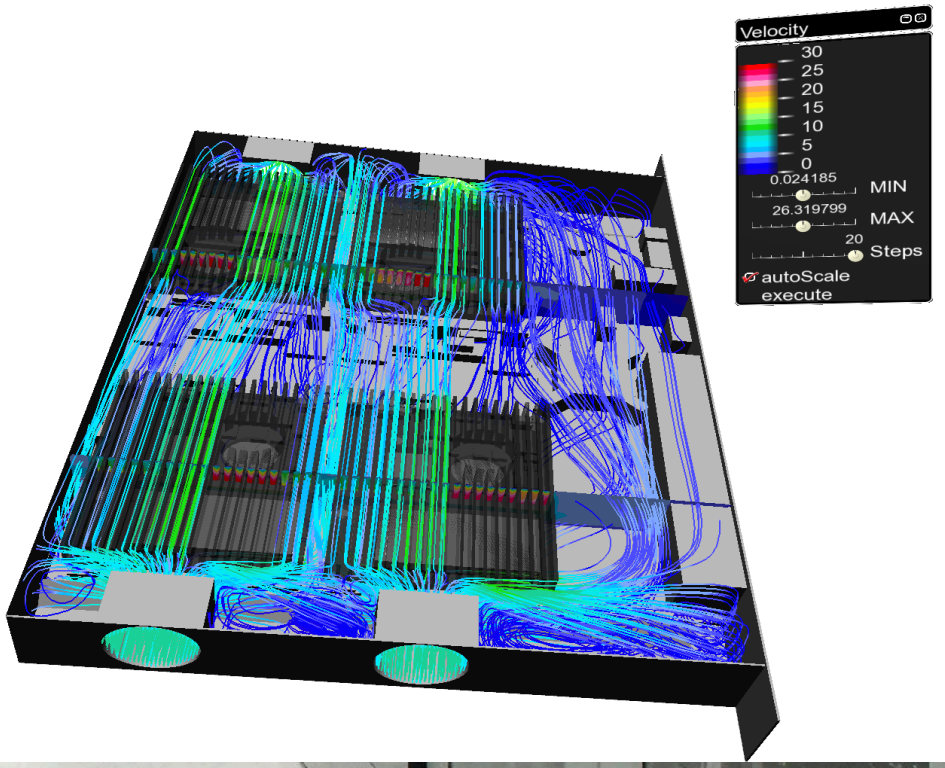
Goal: To select optimal configuration for given workload

Simulating airflow in Servers

Simulating airflow in Servers



Temperature distribution



Airflow distribution

What's next?

SUMMARY

Summary

- CoolEmAll delivers two main products:
  - **Open source SVD toolkit to investigate and assess cooling- and energy-efficiency in data centres based on simulations**
  - **Best practises and open designs ComputeBox blueprints and DEBBs**
- These outcomes allow assessment and minimising the energy consumption of data centres by:
  - **Optimisation** of their **design** and **operation**
  - **Tuning** to specific **workloads** and **conditions**
- Results available on www.coolemall.eu:
  - Monitoring and control platform, application profiler
  - SVD Toolkit - 1st Prototype
  - Open DEBB specification
- Work in progress on 2nd Prototype of SVD Toolkit

Questions?

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