Evolution of the Building Management System in the INFN CNAF Tier-1 datacenter facility

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Summary

▶ The INFN CNAF Tier-1 resources: Infrastructure and IT

▶ Development of a new Building Management System (BMS): requirements and primary objectives

▶ The StruxureWare™ Building Operation software (SBO) architecture

▶ The Power Usage Effectiveness (PUE) and other relevant metrics

▶ Integration with Open Standard (Web Services) and the Tier-1 Monitoring tool

▶ Future development and conclusion

INFN CNAF Tier-1 resources

- **1 Dedicated electrical line** from energy distribution network
- **15,000 V** Voltage
- Up to **4.0 MW** Power
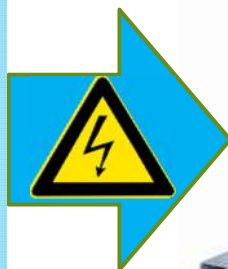
- **3 Tranformers** (2 in production, 1 reserve)
- **2.5 MVA each**
- **15,000 V => 400 V**
- **2 separated 4000 A** electrical distribution **lines** (RED & GREEN)

- **6 EMERSON Chiller**
- **300 KW each** of **cooling capacity**
- Periodic auto-rotation of active vs standby (N+2 rendundancy)
- Integrated freecooling

- **2 EuroDiesel Rotary diesel UPS**
- **1700 KVA** each (1340 KW Real Power with a ~0.8 cosφ)
- 3-5 days autonomy
+
- **1 Standard diesel generator** (no UPS)
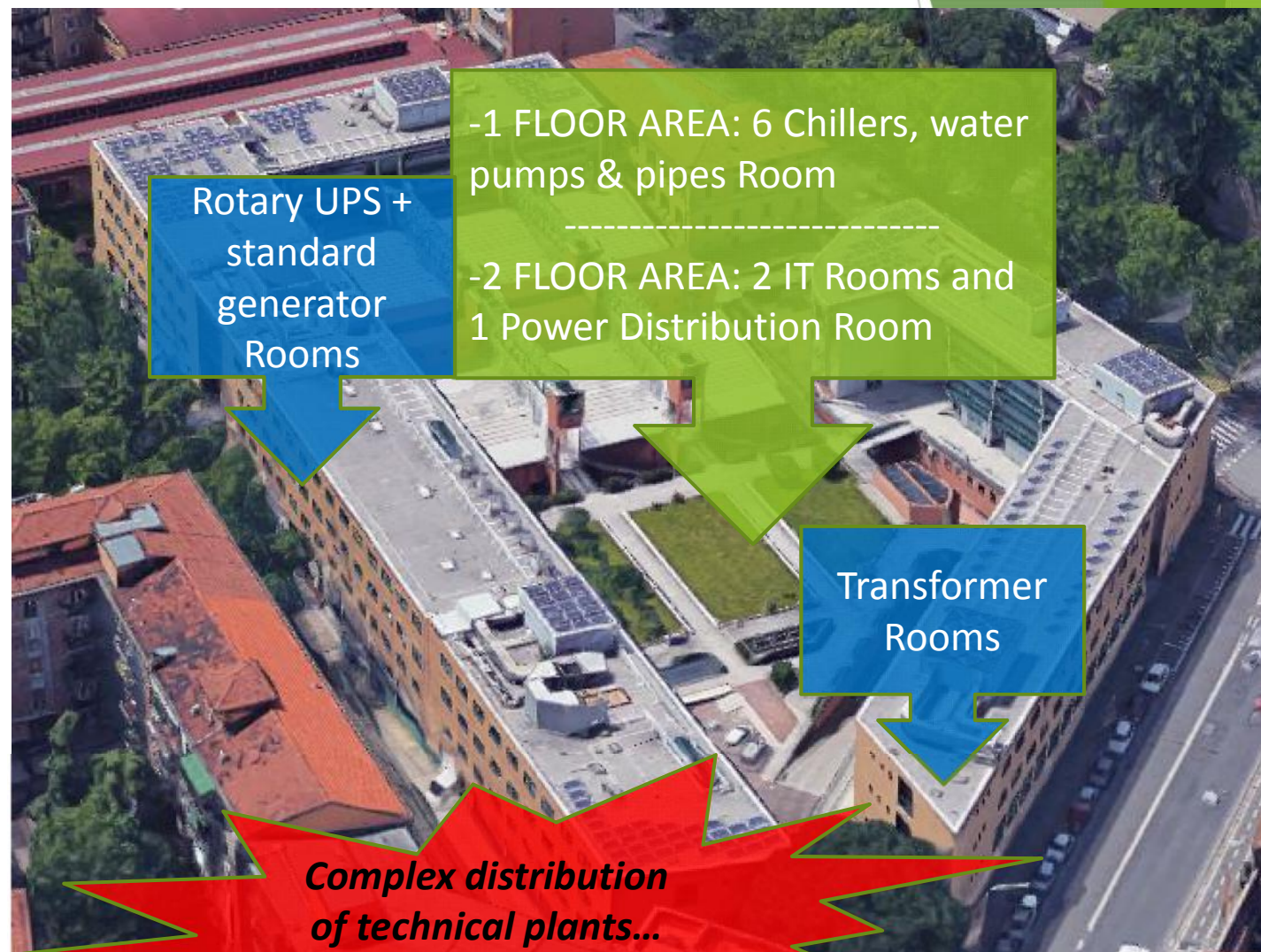- **1250 KVA** can be used for emergency power or not-IT equipment (e.g. chillers)

UPS

IT RESOURCES

3
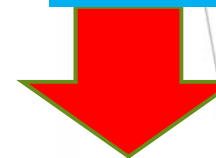
INFN CNAF Tier-1 resources rooms

- ▶ The INFN CNAF Tier1 is hosted in a complex university building ☹

- ▶ Installation used all avaliable space in 2009

- ▶ A total of 1950 m² is used for:

- *2 IT Resources Rooms (250 m² + 350 m²)*
- *4 Additional locations:*
  - *. Tranformers Room*
  - *. UPS Room*
  - *. Chiller Room*
  - *. Power Room*

Rotary UPS + standard generator Rooms

-1 FLOOR AREA: 6 Chillers, water pumps & pipes Room

-2 FLOOR AREA: 2 IT Rooms and 1 Power Distribution Room

Transformer Rooms

Complex distribution of technical plants...
=> DETAILED BMS!

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INFN CNAF Tier-1 IT rooms

▶ **44 APC InRow RP (IRP)** Precision Cooling with 2-ways valves, 3 Fans and humidity control. (Cold water provided by chillers)

▶ 50 KW of cooling capacity each IRP => **1600 KW** with N+2 redundancy in 6 "Aisle" over 2 different rooms

▶ **48** Racks for IT equipment with a 10KW cooling capacity (Room 1=> 2-Aisle)
76 Racks for IT equipment with a 20KW cooling capacity (Room 2=> 4-Aisle)

▶ Hot Aisle containment (<u>without</u> floating floor) with environmental sensors (T&H) in HOT and COLD corridor
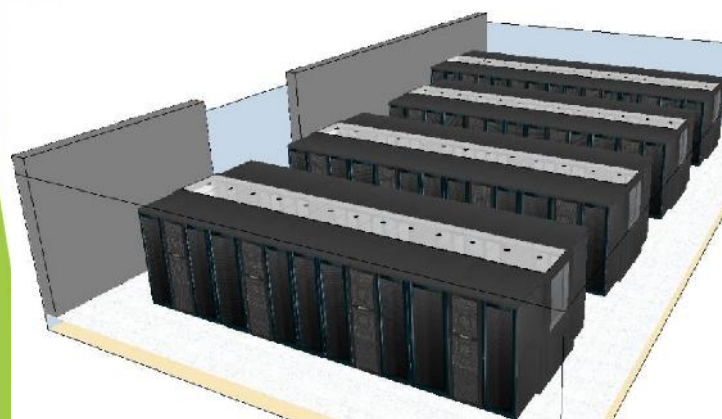
ROOM 2 (4-Aisle)

- **Water Setpoint:** (chillers): <u>15°C /20°C</u>
- **Air T & Humidity Setpoint:** (IRP group control): <u>24°C</u> & <u>45%/60%</u>
- **Cold/Hot detected Air T:** <u>24°C/31°C</u>
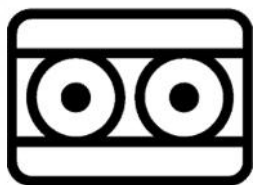
COLD

HOT

COLD

INFN CNAF Tier-1 IT resources

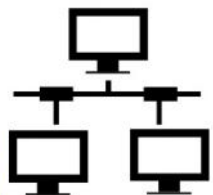Tier-1 for all LHC experiments (Alice, Atlas, CMS, LHCb) and ~20 others non-LHC (including Astroparticle Physics)
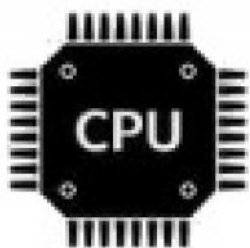
▶ Tier-1 cluster computing power:
205,000 HEP-SPEC06
provided by 22,000 CPU cores

▶ Tier-1 disk space capacity:

▶ Tier-1 tape space capacity:
1 Tape library with 10,000 slot capacity (Oracle SL8500)

▶ Tier-1 network facility:

A new BMS => Objectives:

▶ The old BMS system was the TAC VISTA software:
- currently phasing out… ☹
- Many "cons" (difficult to edit, no compatibility with open protocols, GUI based on Java etc…)

▶ We need a more flexible system that could re-use the "sensors" and "collectors" hardware (to limit the hardware cost of the migration) and improve user-friendly management

▶ The "natural" choice is the **Schneider StruxureWare™ Building Operation software (SBO)** architecture:
- Full compatible with Modbus protocol (TCP/IP and serial)
- Full compatible with the TAC VISTA Lonworks network (re-use cabling&HW)
- The webstation GUI user interface just need a standard browser (no Java or other plugin needed); works directly on mobile devices! ☺
- Open to standard protocols (e.g. webservices serve&consume)
- Migration from TAC VISTA was easily split into 3 phases over 8 weeks period:
    1) TCP Modbus "aisles" & "PLCs" => can run both on VISTA and SBO (6 weeks test phase)
    2) Serial Modbus => OUT on VISTA & IN only on SBO (2 weeks "critical")
    3) Lonworks Network & ALL alarms/trends => ONLY SBO ACTIVE! (2 weeks for finalize)

The Schneider SBO architecture

▶ The core of the software management, web user interface and archiving is based on 2 servers:

    ▶ **Enterprise software server:** runs the core software for management & backup of the configuration.

    ▶ **Report Server**: used for archiving the long-term trends (Microsoft SQL Server) and adds advanced reporting options.

TREND LOGS

- ENTERPRISE SERVER

- REPORTS SERVER + DATABASE

Eth

Eth

PRIVATE LAN
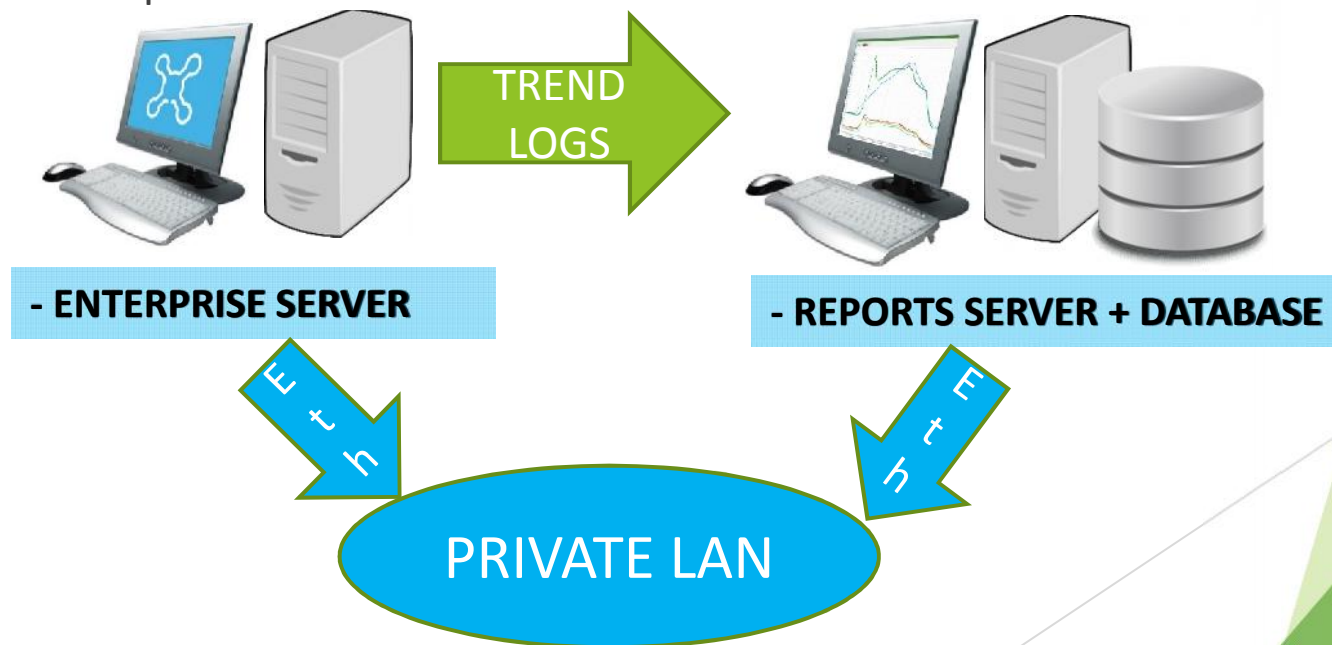
The Schneider SBO architecture

- **3 Automation Servers** provide the "engines" for the **BMS system**, in 3 "strategic" physical locations (-1 Floor Area, Power Distribution Room & Tranformer Room):

  - Runs stands-alone

  - Collect data directly from the Lonwork Network, Modbus Serial and Modbus TCP (PLCs) and provides control logic

LON NETWORK
~30 "Xenta Family" programmable modules (reused from TAC)
~300 "Points" (variables or states)
2 separated bus Implements control logic (e.g. chiller rotation)

PRIVATE LAN

Eth
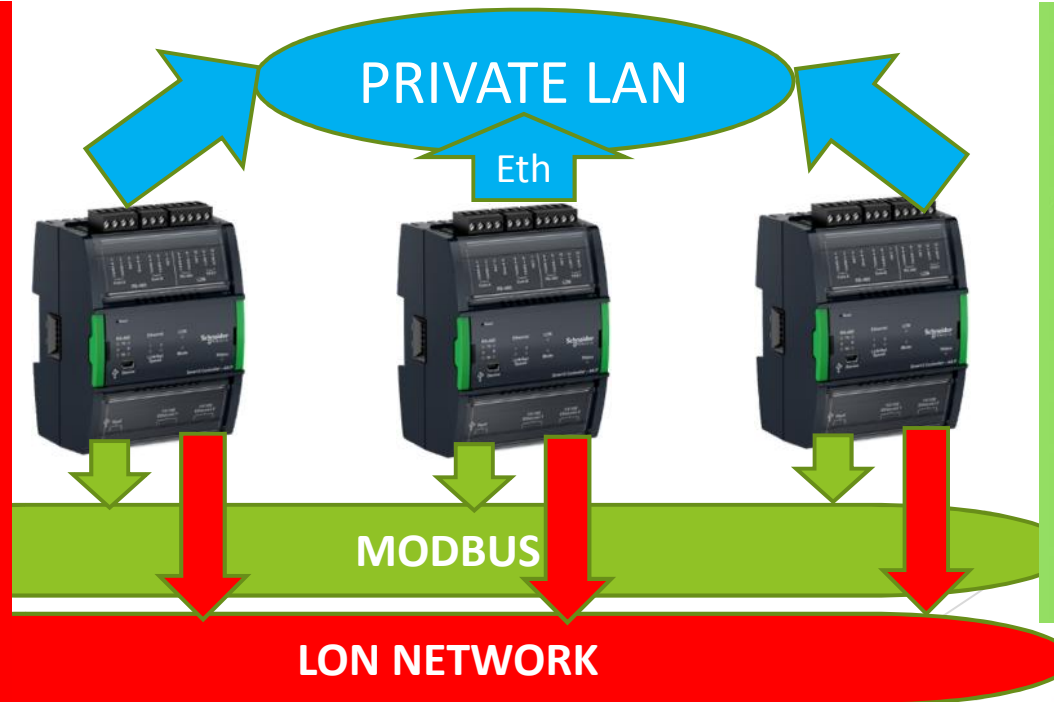
MODBUS

LON NETWORK

MODBUS NETWORK
Use both Serial (rs484/rs232) and TCP/IP
~4500 "Points" (variables or states)
Connection to 6 reduntand PLCs (PLCs are used for electrical switch logic & electric measuring instrument)

The Data Center Expert

▶ The Tier-1 BMS is integrated by another Schneider (formerly APC) software package: **The StruXureware Data Center Expert (DCE)**

▶ Fine monitoring, tuning and notification over the Datacenter "Aisles" components and Metered Power Distribution Units (PDUs)

▶ With the MODBUS TCP Output Module => **DIRECT INTEGRATION IN SBO**

TEMPERATURE
18-set-2016 15.47.20 - 19-set-2016 15.47.20

ROOM 2 AISLE 4
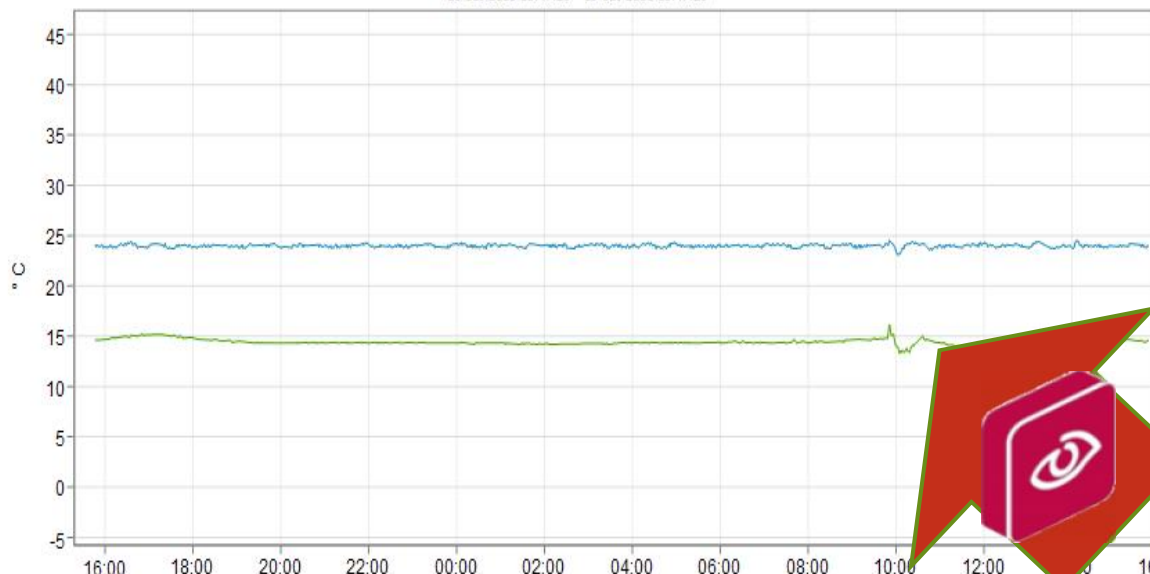
ROOM 2 AISLE 4

Totale sensori:11

| Colore	Dispositivo monitorato	Sensore	Unità	Ultimo val...	Valore mi...	Valore ma...
☑	RP-02 (10.0.2.32)	Temperature Fluid IN		14,4	13,3	16,1
☑	RP-02 (10.0.2.32)	Temperature Air OUT		23,9	23,1	24,5

The INFN CNAF Tier-1 BMS

▶ Power Switch state, Electrical values, Temperature & Humidity values, Fan states etc...

▶ Mail alarms notification fully customizable

▶ User-friendly Grafic Pages for <u>HVAC</u> *(Heat, Ventilation and Air Conditioning)*, <u>Electrical circuit diagrams</u>, <u>Mechanical Pages</u>, <u>Fire prevention system</u>, <u>Flooding&Water Leaking</u> (-2 Floor) etc...
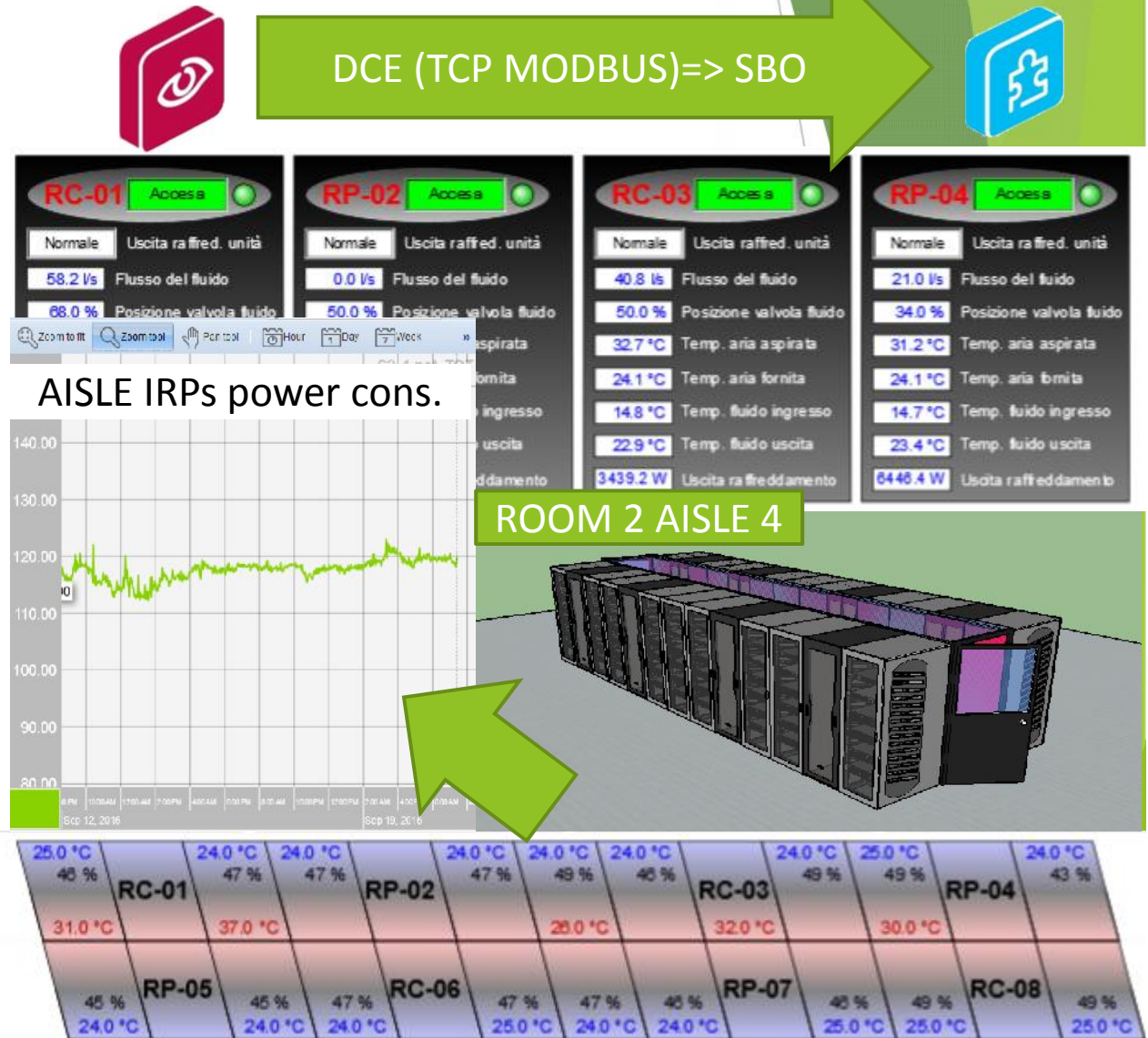
WATER PUMPS
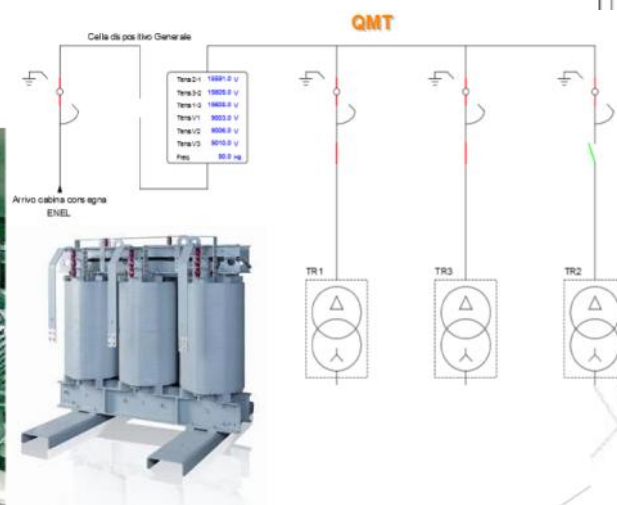
The INFN CNAF Tier-1 BMS

▶ Information from the DCE software are integrated in SBO

SBO is the central "entry point" for the **INFN CNAF Tier1 BMS!**

DCE (TCP MODBUS)=> SBO

	RC-01 Accesa	RP-02 Accesa	RC-03 Accesa	RP-04 Accesa
Normale Uscita raffred. unità		Normale Uscita raffred. unità	Normale Uscita raffred. unità	Normale Uscita ra fred. unità
Flusso del fluido	58.2 l/s	0.0 l/s	40.8 l/s	21.0 l/s
Posizione valvola fluido	68.0 %	50.0 %	50.0 %	34.0 %
Temp. aria aspirata			32.7 °C	31.2 °C
Temp. aria fornita			24.1 °C	24.1 °C
Temp. fluido ingresso			14.8 °C	14.7 °C
Temp. fluido uscita			22.9 °C	23.4 °C
Uscita raffreddamento			3439.2 W	6446.4 W

AISLE IRPs power cons.

ROOM 2 AISLE 4

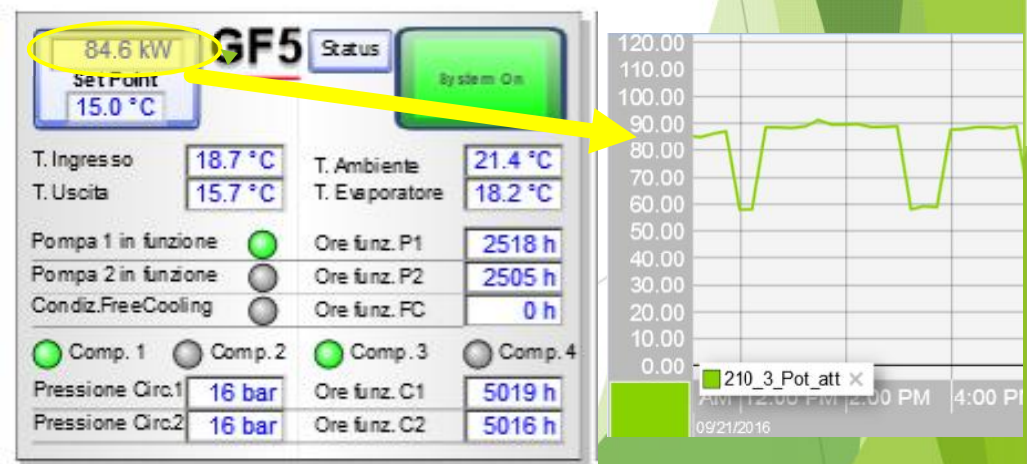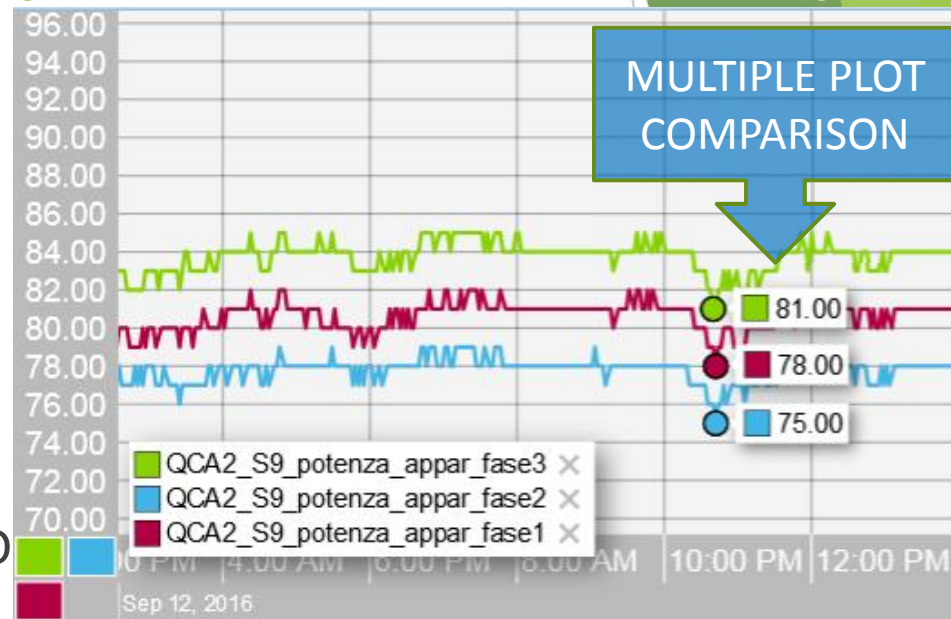|				
25.0 °C 46 % RC-01	24.0 °C 47 %	24.0 °C 47 % RP-02	24.0 °C 47 %	24.0 °C 49 % RC-03	24.0 °C 46 %	24.0 °C 49 %	25.0 °C 49 % RP-04	24.0 °C 43 %
31.0 °C	37.0 °C		26.0 °C	32.0 °C	30.0 °C	
45 % RP-05 24.0 °C	45 % RC-06 24.0 °C	47 % 25.0 °C	47 % RP-07 24.0 °C	46 % 24.0 °C	48 % RC-08 25.0 °C	49 % 25.0 °C	49 % 25.0 °C

BMS METRICS (LOGS & TRENDS)

▶ The **metrics** (*state* and *variable* values) are one of the <u>most important features</u> of an optimal **BMS.**

▶ LOGS & TRENDS represents the "history" of the physical quantities in the technical plants & datacenter rooms.

▶ Essential for:
   ▶ Identification of periodic "hot spots" or critical area
   ▶ Datacenter HVAC/Power optimization
   ▶ Reverse engineering of specific conditions
   ▶ Data center Power/HVAC outage or major failure (fire) analysis

BMS METRICS (LOGS & TRENDS)

▶ The SBO architecture has increased the number of metrics we are collectiong and the archiving duration (=> Report Server & database)

  ▶ Over 2500 LOGS & TRENDS collected! => HIGH DETAILS
  ▶ Intuitive system GUI => TREND
  ▶ 15 minutes granularity
  ▶ Optimized for variable state (e.g. a power switch condition is logged <u>only</u> when a change occurs)
  ▶ Over 10 years of history possible
    (but it is just started ☺!)

MULTIPLE PLOT COMPARISON

81.00
78.00
75.00

QCA2_S9_potenza_appar_fase3 ×
QCA2_S9_potenza_appar_fase2 ×
QCA2_S9_potenza_appar_fase1 ×

Sep 12, 2016

84.6 kW GF5 Status System On
Set Point
15.0 °C

T. Ingresso 18.7 °C   T. Ambiente 21.4 °C
T. Uscita   15.7 °C   T. Evaporatore 18.2 °C

Pompa 1 in funzione ●   Ore funz. P1 2518 h
Pompa 2 in funzione ○   Ore funz. P2 2505 h
Condiz.FreeCooling ○   Ore funz. FC   0 h

● Comp. 1 ○ Comp. 2 ● Comp. 3 ○ Comp. 4
Pressione Circ.1 16 bar   Ore funz. C1 5019 h
Pressione Circ.2 16 bar   Ore funz. C2 5016 h

210_3_Pot_att ×
09/21/2016

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BMS METRICS (PUE and pPUE)

From Wikipedia => "*Power usage effectiveness (PUE) is a measure of how efficiently a computer data center uses energy; specifically, how much energy is used by the computing equipment (in contrast to cooling and other overhead).*"

▶ Increasing cost of Electrical Power => PUE reduction is fundamental!!!
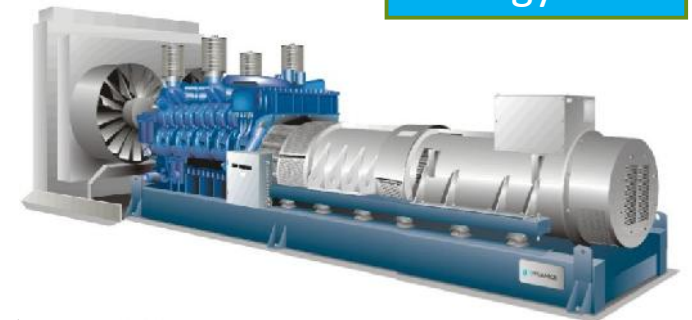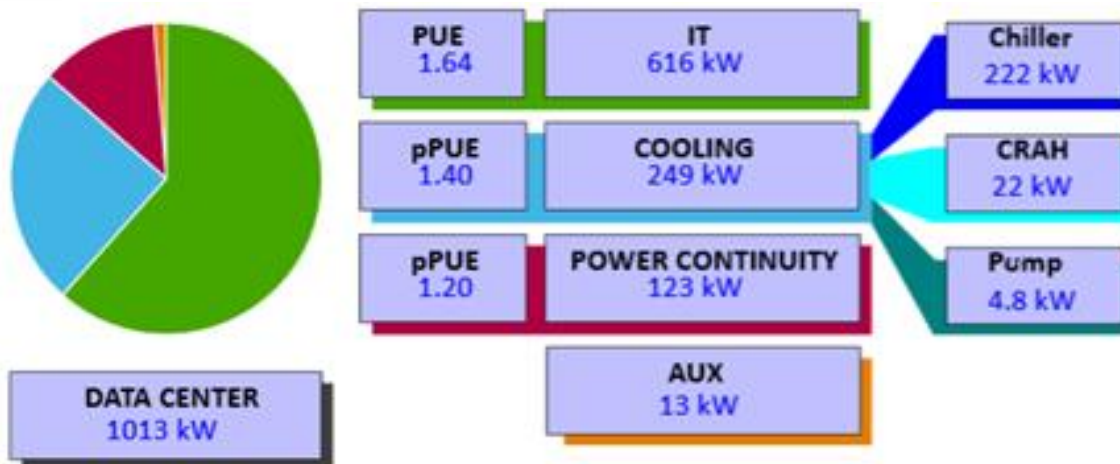
$$PUE = \frac{Total\ Energy}{IT\ Energy}$$

▶ We also introduce the partialPUE (pPUE) in order to monitor the power demands specific area of the infrastructure and optimize them

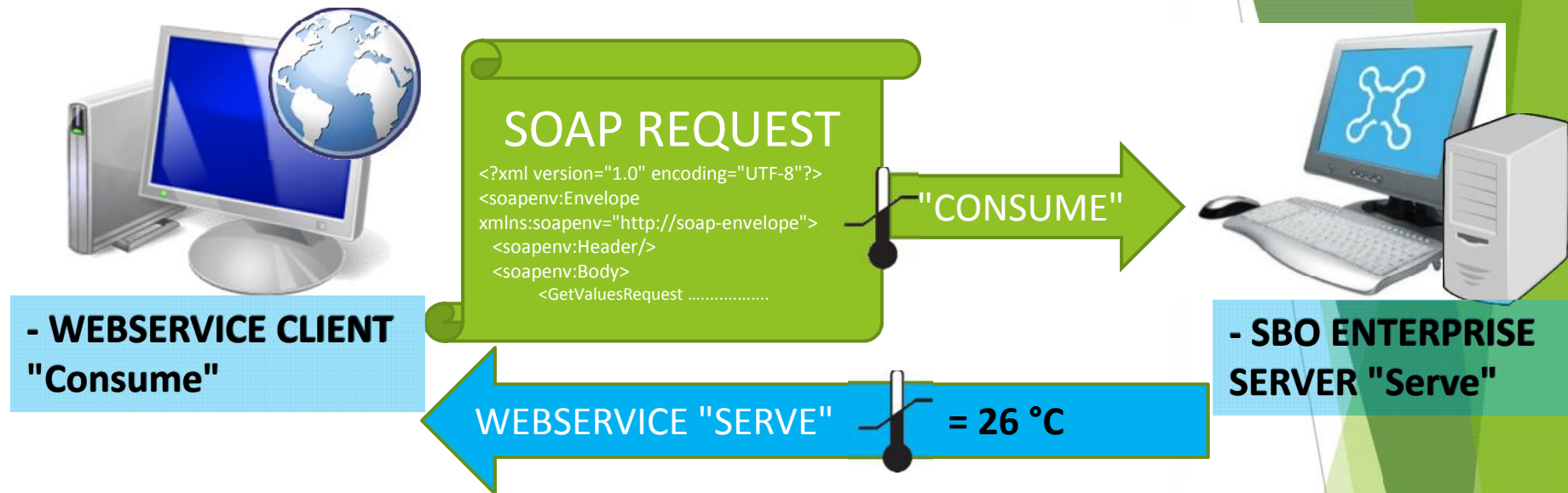$$e.g.\ POWER\ CONTINUITY\ pPUE = \frac{UPS\ Energy + IT\ Energy}{IT\ Energy}$$

Indicator of the Rotary Diesel Power Continuity Energy Loss

PUE 1.64	IT 616 kW	Chiller 222 kW
pPUE 1.40	COOLING 249 kW	CRAH 22 kW
pPUE 1.20	POWER CONTINUITY 123 kW	Pump 4.8 kW
	AUX 13 kW	

DATA CENTER 1013 kW

TR1 On 451 kW TR2 Off 0 kW TR3 On 555 kW

BMS open standards (Web Services)

SOAP REQUEST

```
<?xml version="1.0" encoding="UTF-8"?>
<soapenv:Envelope
xmlns:soapenv="http://soap-envelope">
   <soapenv:Header/>
   <soapenv:Body>
        <GetValuesRequest ………………
```

"CONSUME"

WEBSERVICE "SERVE"   = 26 °C

- WEBSERVICE CLIENT "Consume"

- SBO ENTERPRISE SERVER "Serve"

▶ **Serve & Consume** Web Services capability of the SBO software

▶ **SOAP** request using standard code

▶ NDA Agreement signed with Schneider for the Web Services **Serve** of "strategic" variables

▶ Access to the "current value" of BMS variables from the INFN CNAF Tier-1 Monitoring Infrastructure *(see next slide)*

▶ Future implementation fot the Web Services SBO **Consume** e.g. connecting to external weather forecast => Automatic adjust of HVAC scheduling

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Tier-1 Monitoring Infrastructure

▶ Monitoring made with Opensource components:

Backend

▶ Metrics: Sensu for standard metric measurements + custom python scripts (implementation of SOAP requests)
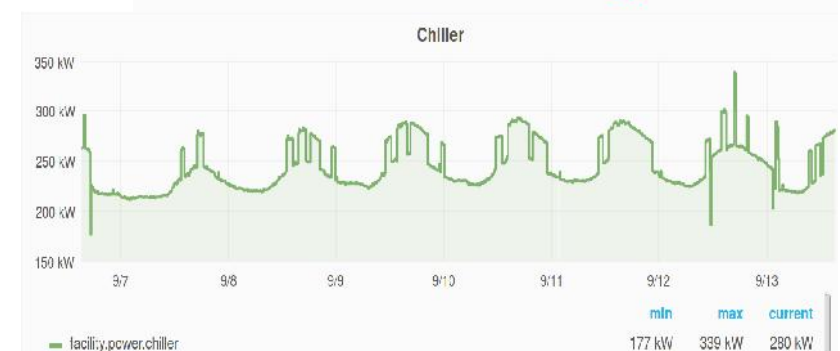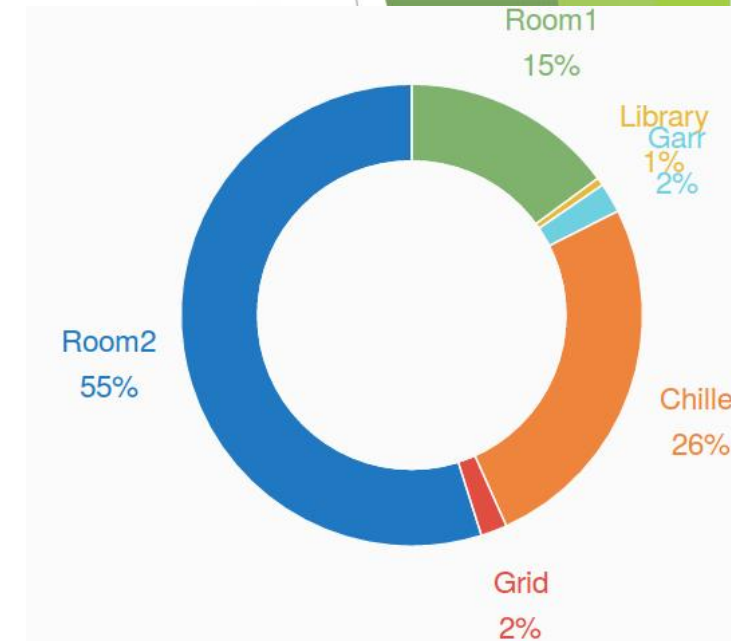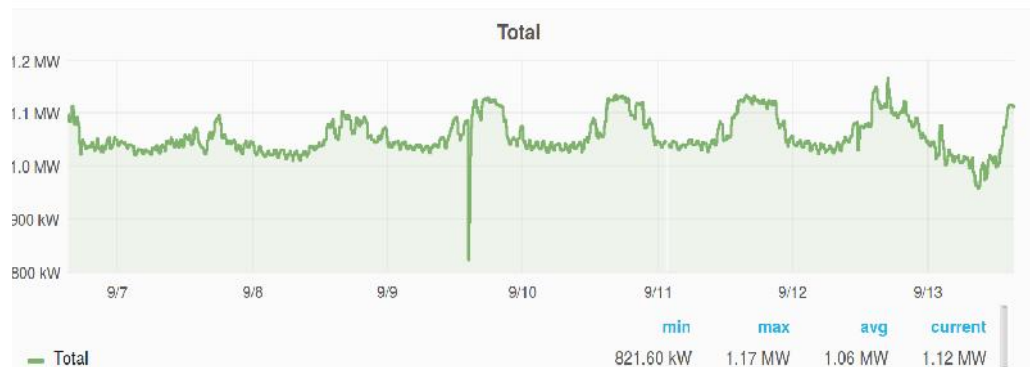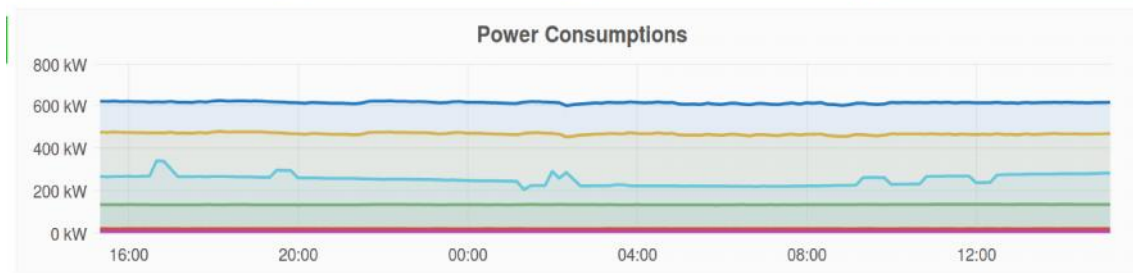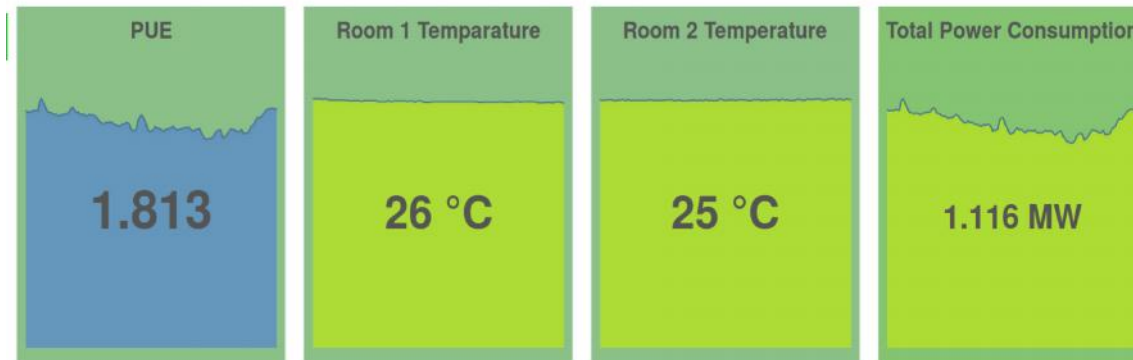
▶ Data Storage: InfluxDB, Whisper

Frontend

▶ Uchiwa for notifications and status
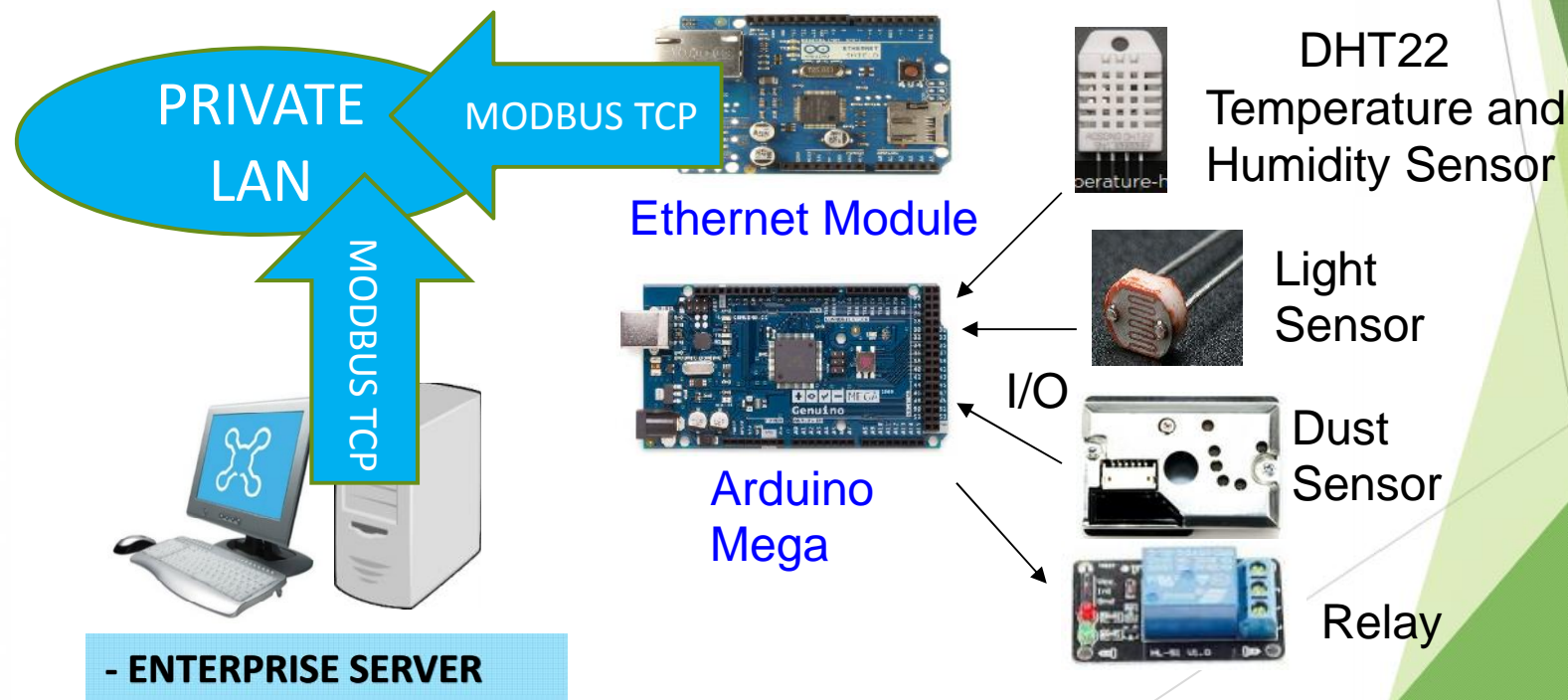
▶ Grafana for charting

Tier-1 Facility Dashboard

TCP MODBUS sensors expansions

▶ A study for using low-cost platforms (Arduino with specific modules) as Modbus compatible sensors collector is under way...

▶ Could be used for additional/redundant monitoring with a minimum economical effort.

▶ Could help providing very "custom" sensors (e.g. "home made" dust sensor)

PRIVATE LAN

MODBUS TCP

MODBUS TCP

Ethernet Module

Arduino Mega

I/O

DHT22 Temperature and Humidity Sensor

Light Sensor

Dust Sensor

Relay

- ENTERPRISE SERVER

Conclusion

▶ The BMS choice for the DCE/SBO software for migration was successful
=> Good reliability and Great compatibility!

▶ Our PUE and pPUE analysis show we need big improvement!
- Increase chiller efficiency => project for a chiller tech refresh
- Fine granularity of rack power consumption => increase the number of metered PDUs
- Rotary UPS power loss => big issue ☹

▶ The SBO compatibility with open standard (WEB SERVICES) improve our BMS integration and "open-mindedness"

▶ Standardization of comunication (MODBUS) => Possibility to integrate different platforms (e.g. the Arduino tests)

THANKS FOR YOUR ATTENTION!