CommONEnergy

The importance of innovation – technologies improving comfort and reducing energy consumption in shopping centres

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EURAC Research Bolzano

Energy Day, June 13, 2016
Smart strategies and policies for sustainable shopping centres: energy efficient and cost-competitive retrofitting solutions

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Focus on techologies ...

Spotlight on technologies for shopping centres retrofitting:

- natural ventilation and ventilative cooling
- daylighting and advanced artificial lighting approach for energy efficiency
- HVAC&refrigeration
- i-BEMS for smart supervision and management of shopping centres

+ other energy retrofitting solutions

- Modular Multi-functional Climate Adaptive façade system
- Multi-functional smart coating
- Greenery integration
- Panel for Thermal&Acoustic requalification
- Integration of solar collector in building envelope and energy system
- Storage (battery + H2) and Grid Interaction

... and support tools

- integrated design process
- integrative modelling environment
- Lean Construction Management procedures
- continuous commissioning

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Natural ventilation

OBJECTIVES

The CommONEnergy project investigates the retrofit opportunities to exploit natural ventilation in transitional spaces and to reduce energy consumption for:

- cooling
- mechanical ventilation

CONTEXT

- absence of free cooling strategies
- basic HVAC equipment with constant air volume
- lack of bioclimatic solutions
- no outdoor air economizer
- no night ventilation
- automated windows for smoke ventilation only
- lack of design methods for natural ventilation
- thermal adaptation capability of building occupants not taken into account

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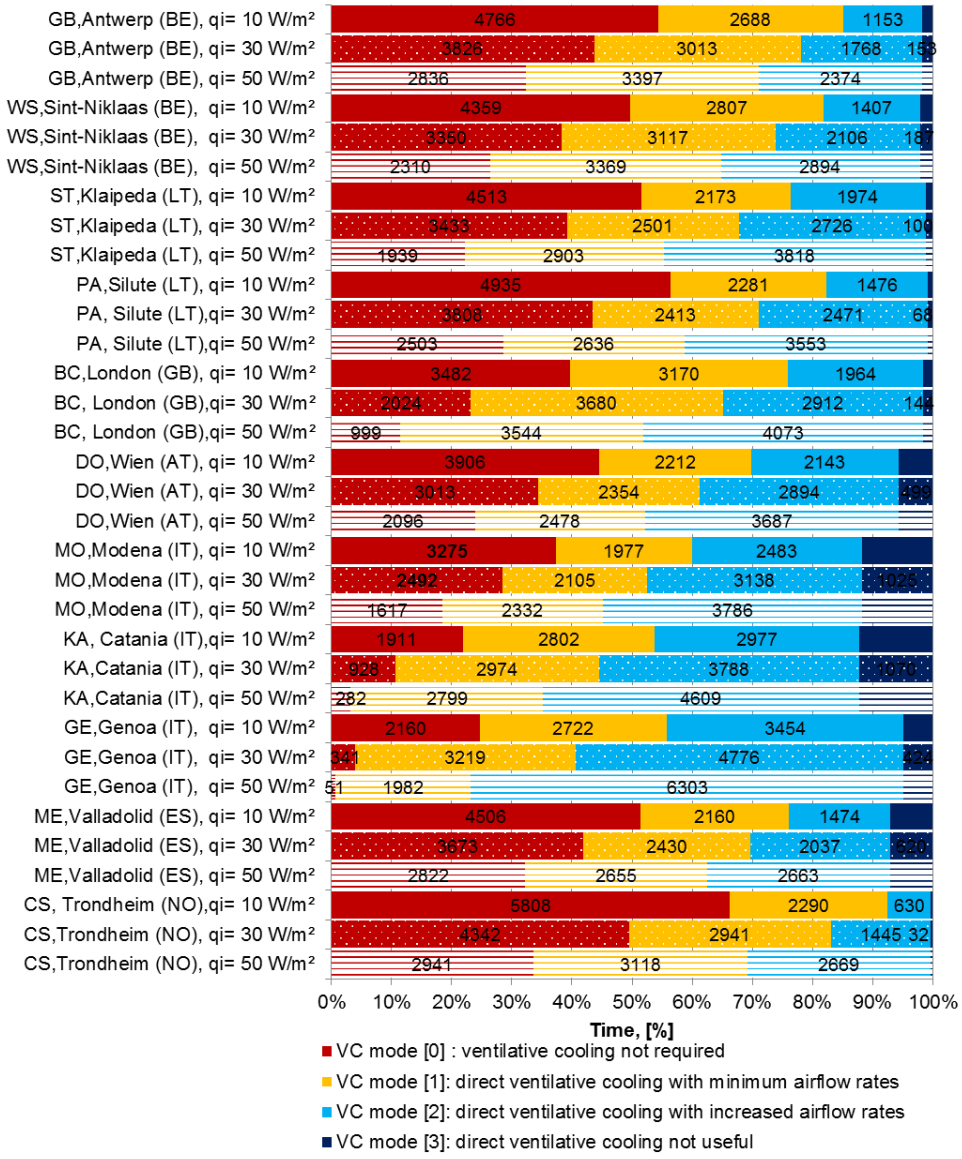
Natural ventilation: climate potential

Ventilative cooling potential tool developed in collaboration with IEA EBC Annex 62



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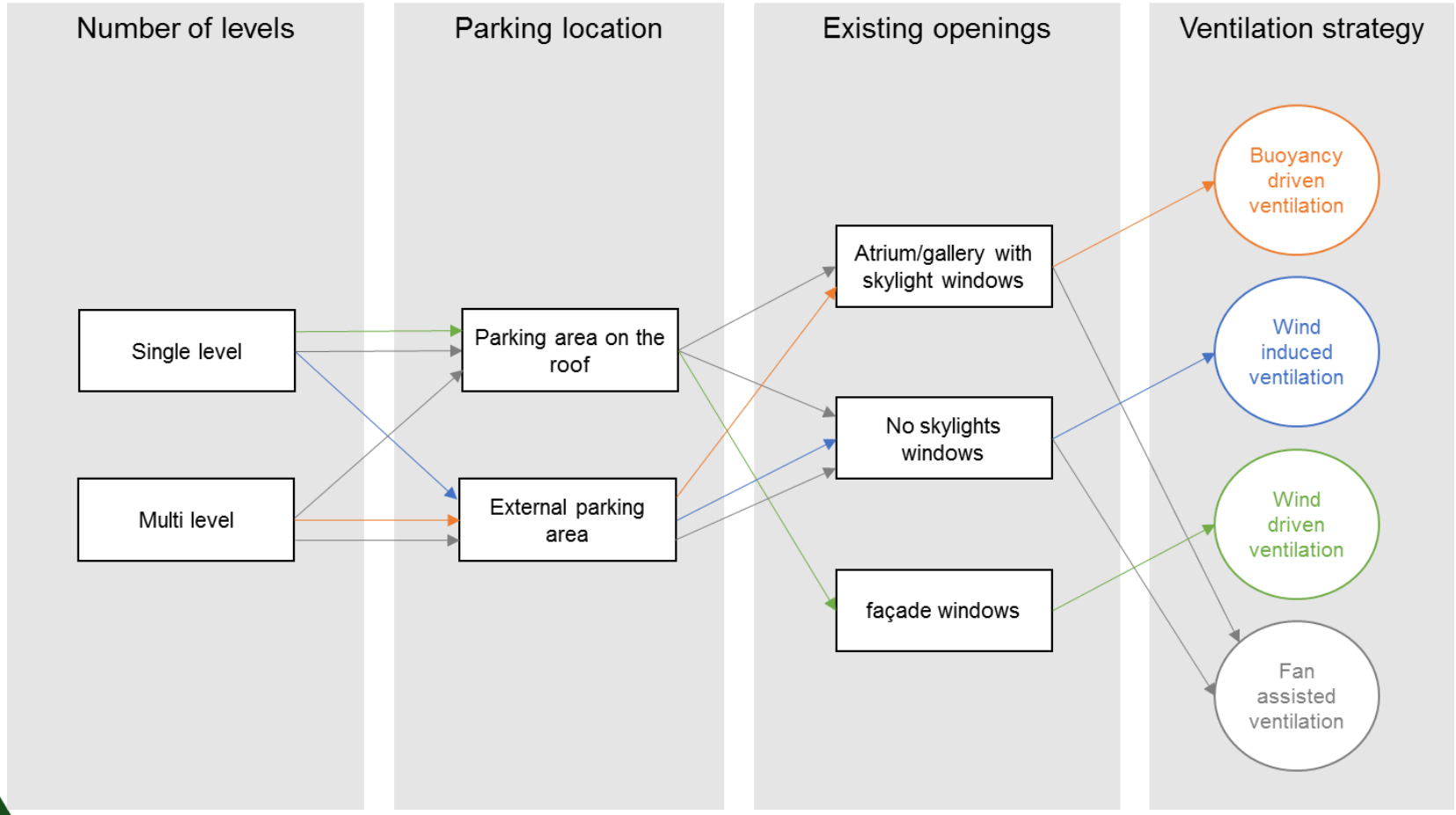
Natural ventilation: architectural constrains



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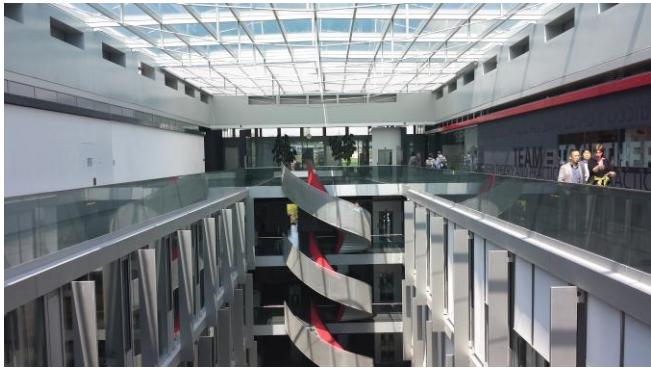
Natural ventilation: strategies

Enhanced displacement ventilation activates free cooling: mechanical ventilation system to maintain min. required ACR and natural displacement ventilation to free cool the zone;



Enhanced stack ventilation in atria to free-cool common areas where temperature and humidity floats without limits: minimum required ventilation rate to maintain an acceptable indoor air quality is provided by the mechanical system until outdoor conditions allows natural displacement ventilation;

Single side stack ventilation: automated openings in the façade to provide free cooling of the single building zone when outdoor conditions are suitable.

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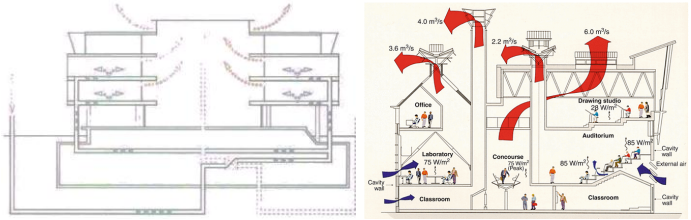
Natural ventilation: technologies

- **Airflow Guiding Ventilation Components**, such as windows, skylights, doors, dampers, flaps, louvres plus special effect ventilators;
- **Airflow Forcing Ventilation Components**, such as such as buoyancy chimneys, solar chimneys, atria, Venturi roofs, powerless roof ventilators, wind towers and wind scoops;
- **Actuators**, such as linear push-pull pistons, rack and pinion systems, chain activators.



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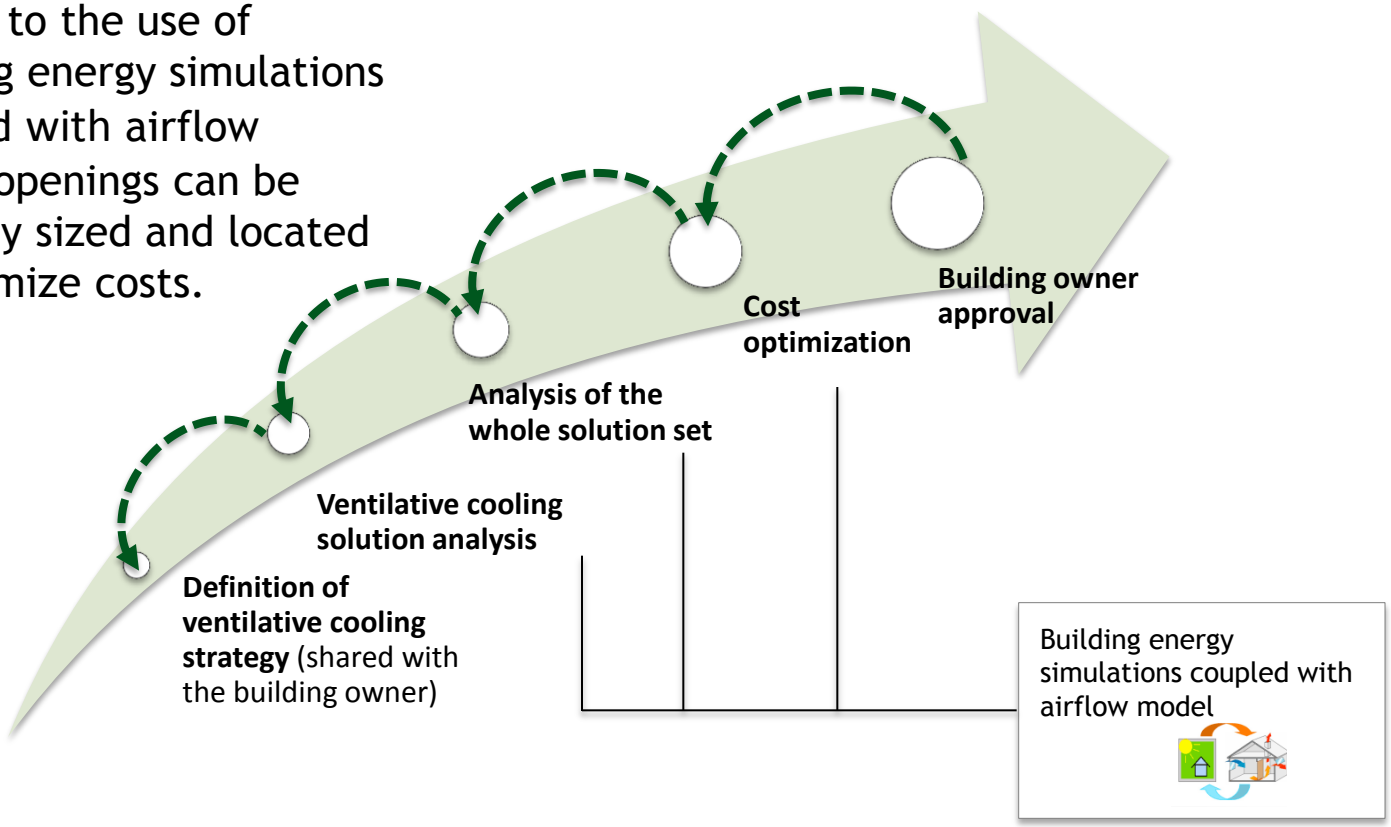
Natural ventilation: design process

Thanks to the use of building energy simulations coupled with airflow model openings can be properly sized and located to optimize costs.



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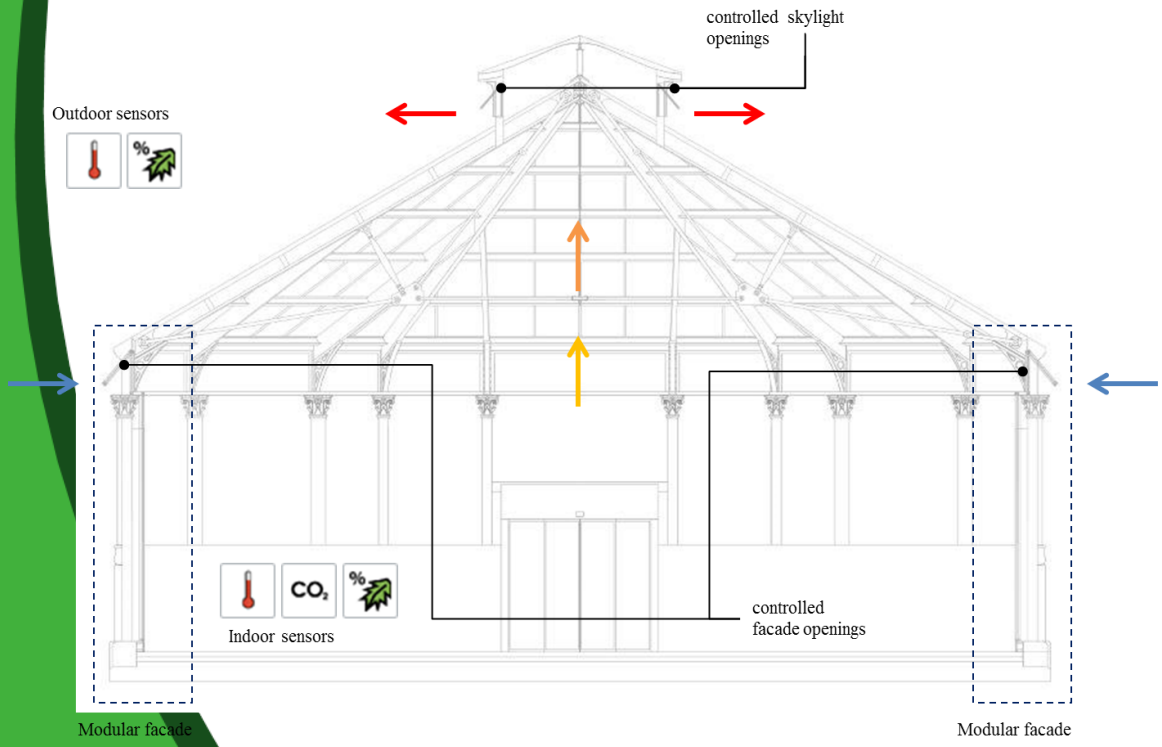
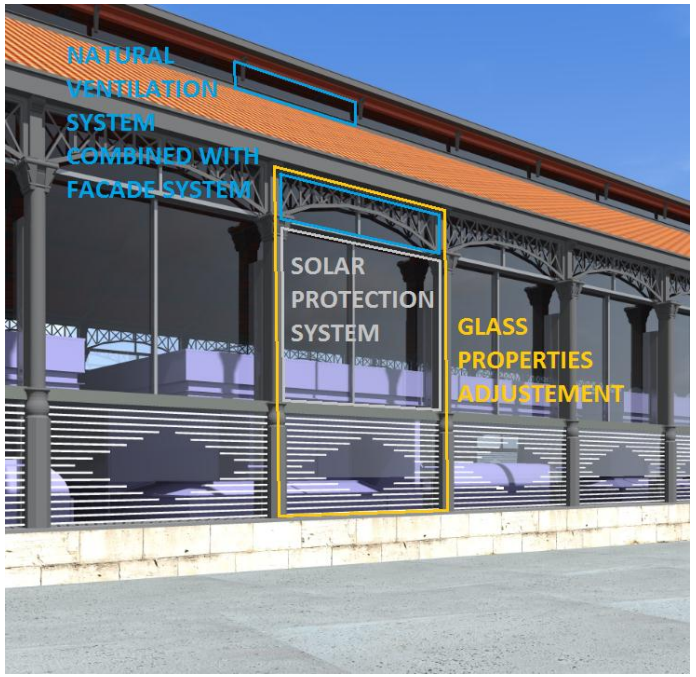
Natural ventilation: demo Mercado del Val





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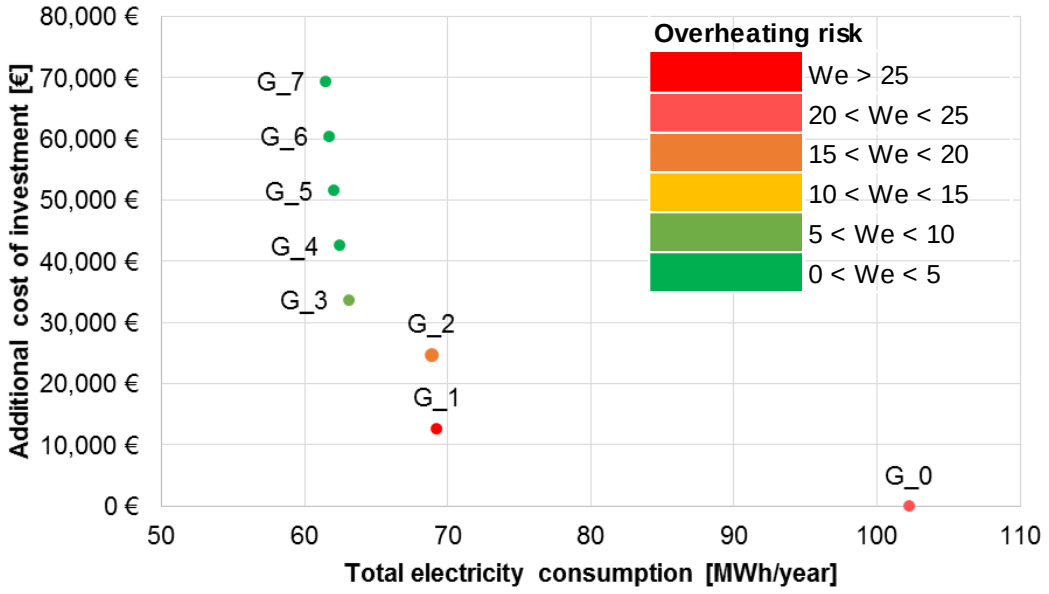
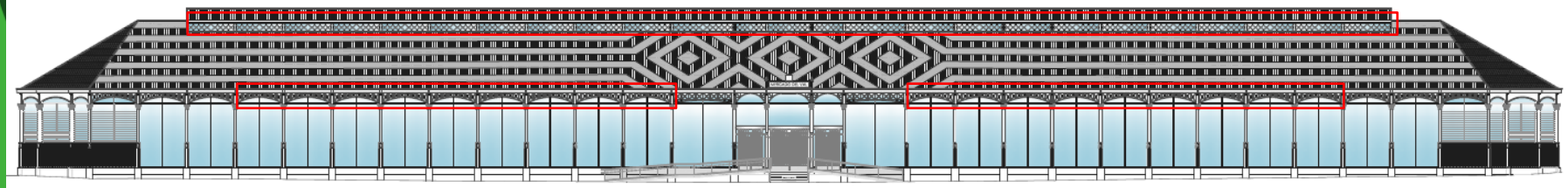
Natural ventilation: demo Mercado del Val

COSTS&BENEFITS ANALYSIS



	nr of windows per facade	nr of windows in the skylight per facade
G_0	0	0
G_1	12	4
G_2	16	8
G_3	20	10
G_4	24	12
G_5	28	14
G_6	32	16
G_7	36	18



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Natural ventilation: demo CitySyd

The system Ve03K which supplies 20'000 m³/hr to common areas is **central damped**	**Fan inverter** controlled by the iBEMS to switch off the mechanical ventilation in the common areas when natural ventilation can be activated
Skylight openings' control protocol not known and therefore, in case of complains about draughts, overridden by manual controls	Connection to the **iBEMS** and the IEQ monitoring system
Overheating problems in the main entrance due to the extensive glazed façade.	Limit the potential for summertime overheating by defining a **new control strategy** for skylight openings and entrance doors
Cold draughts problems occur in the cafeteria area, located at the second mezzanine floor in the atrium.	Limit the potential for cold draughts in wintertime by defining **opening modulation** and by controlling the west windows row separately from the east windows row

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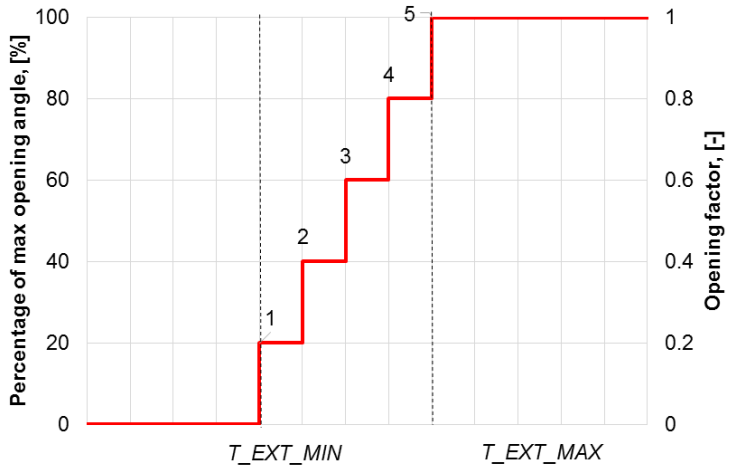
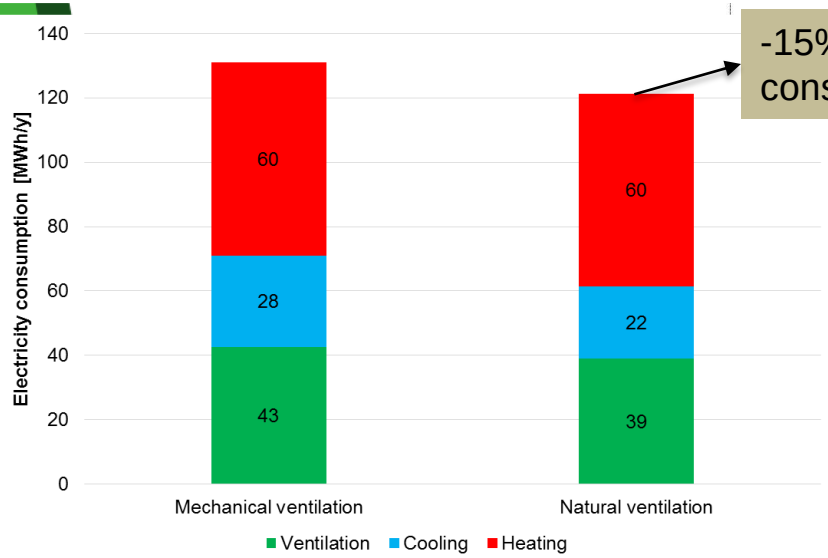
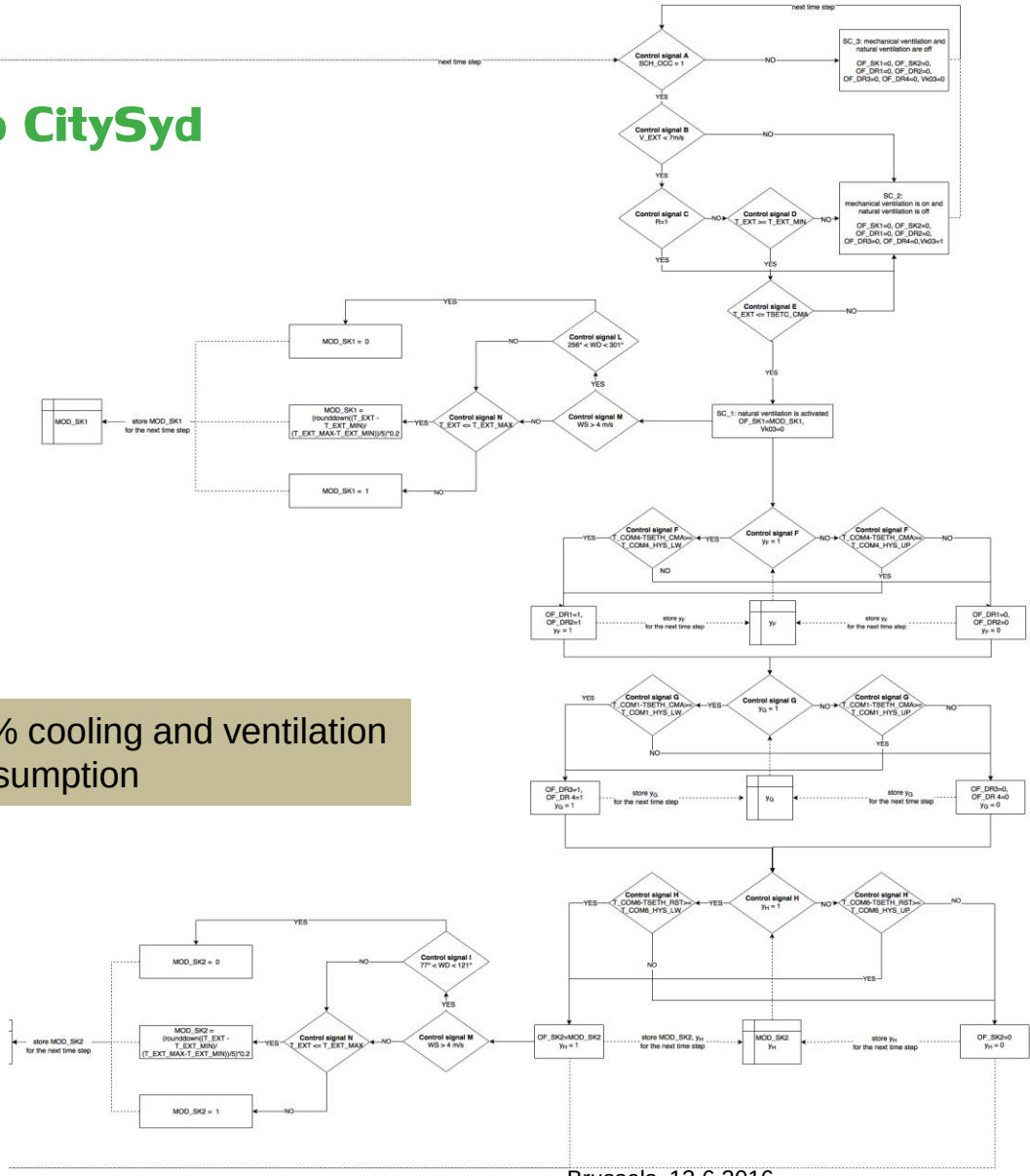
Natural ventilation: demo CitySyd





-15% cooling and ventilation consumption



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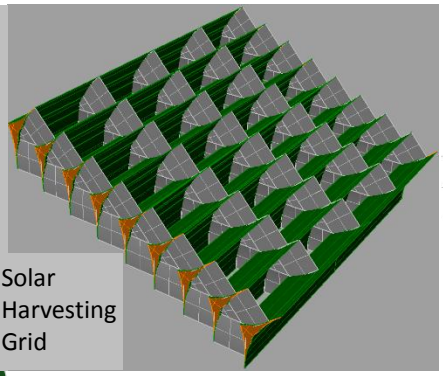
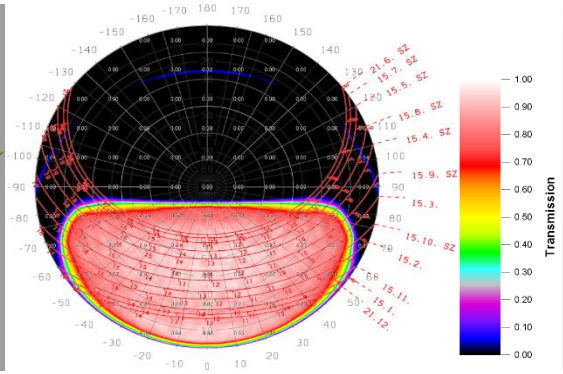
Lighting

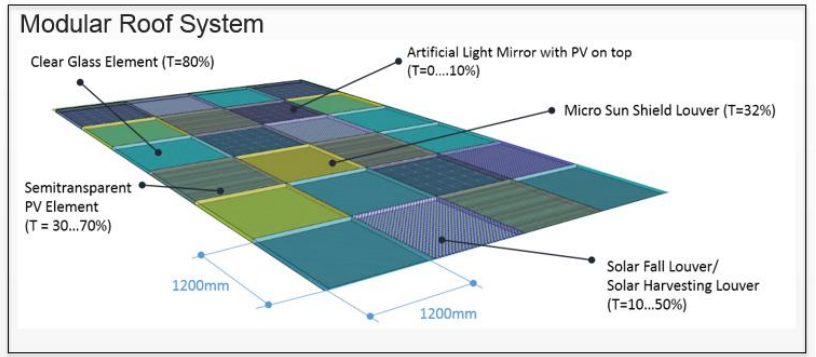
- Analysis of inefficiencies in shopping malls
- Development of strategies for daylighting and artificial light
- Development of daylight- and artificial light- system

DAYLIGHT SYSTEM



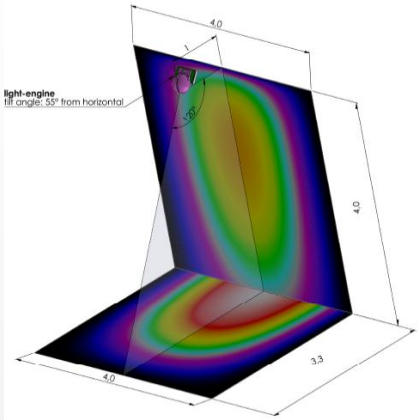
Solar Harvesting Grid

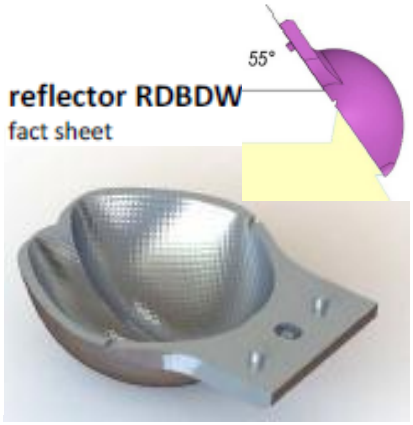


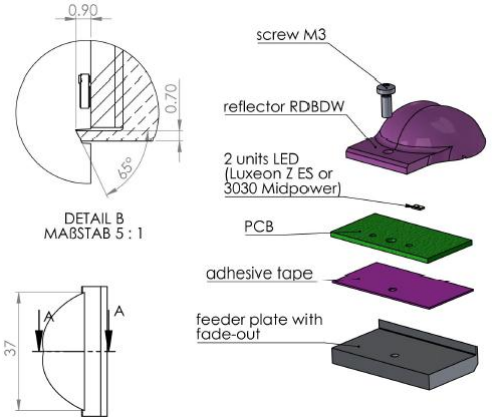


ARTIFICIAL LIGHTING

High Lumen Wallwasher







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Lighting: inefficiency in demo case shop

Actual state in the Trondheim shop

- No daylight harvesting
- No control, e.g. reduced intensities or different light colour
- Glare
- High overall intensities
- Out-dated lightsource: Metal halide lamp
- No dedicated lighting concept to guide customers

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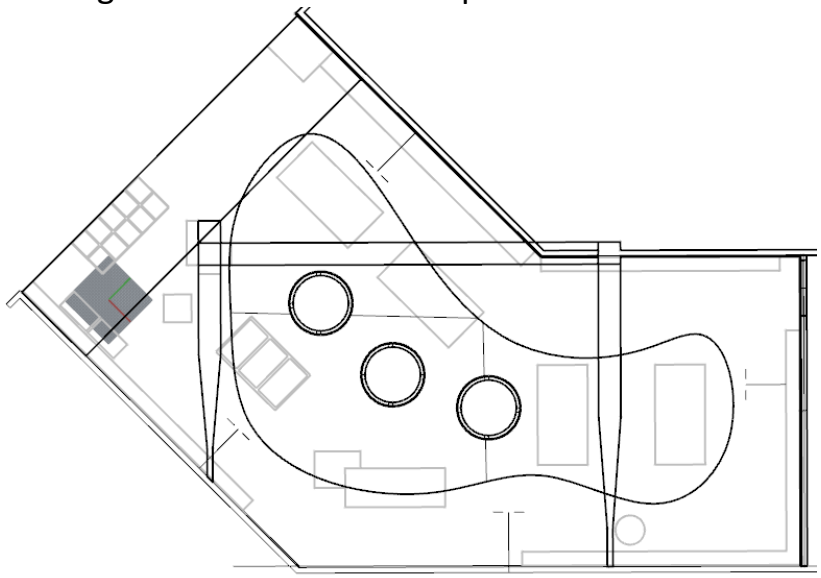
Lighting: daylight harvesting

Planning for the Trondheim shop



Examples of the light tube

"The profit from increased sales is at least worth more than 19 times higher that the energy savings"
(Heschong 2003, California Government)

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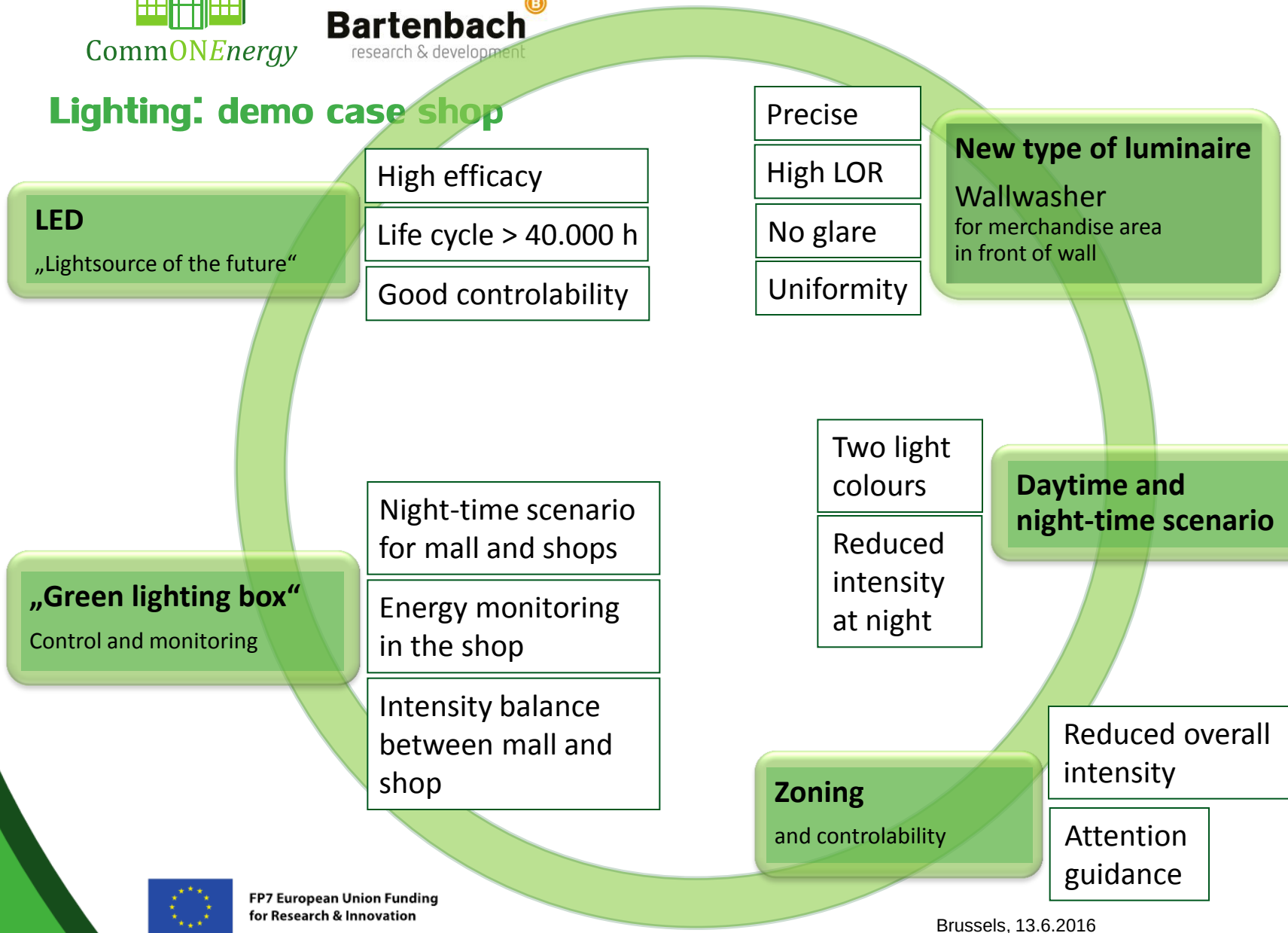
Lighting: demo case shop



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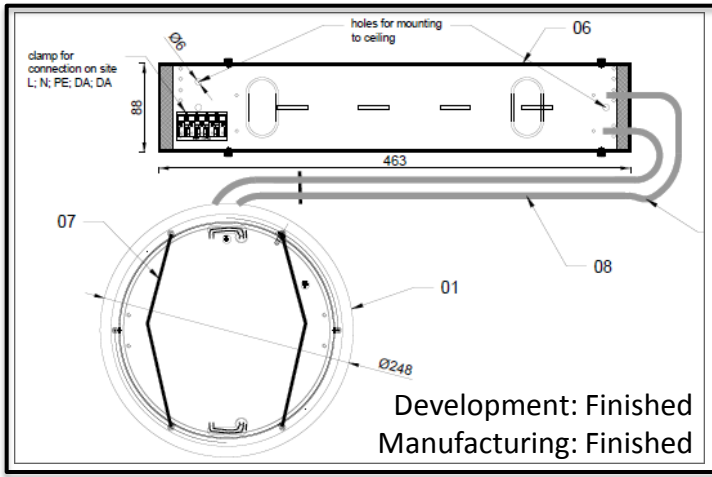
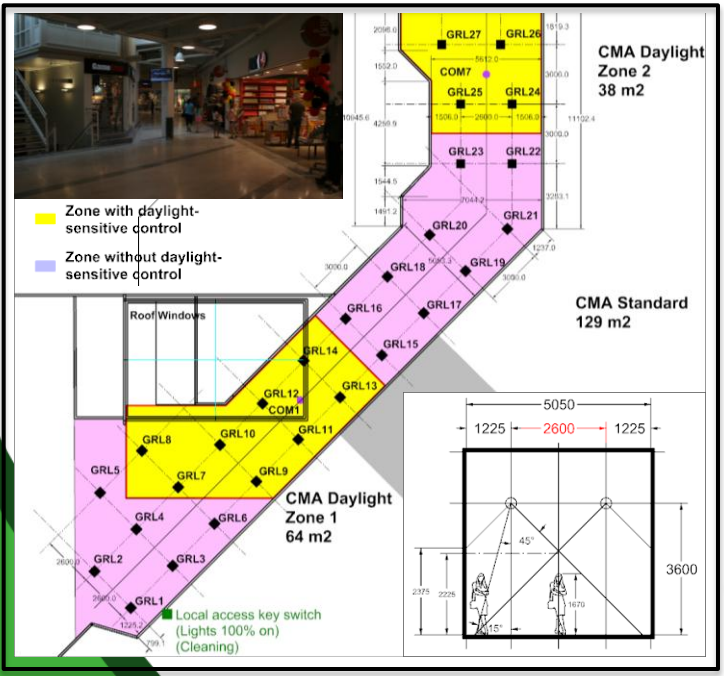
Lighting: General Retail Lighting GRL



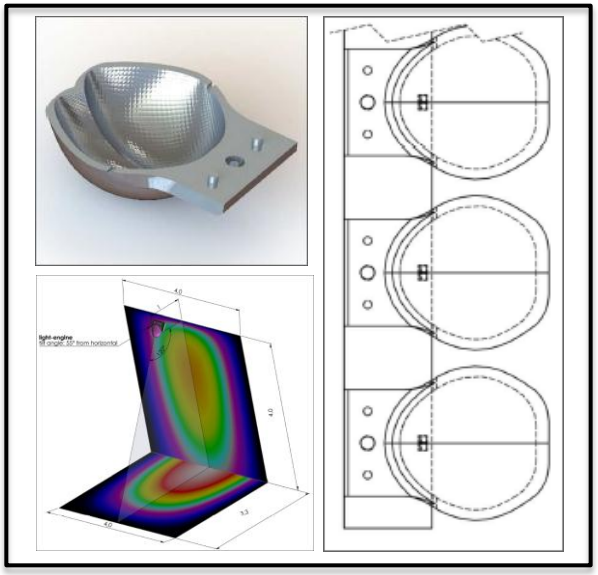
Development: Finished
Manufacturing: Finished



- Application: General lighting for mall and shops
- 2 LED light sources:
  → 7 Downlights as highly efficient functional, directional light source (free-form reflector design)
  → Backlit Area with diffuse light characteristic for enhanced modelling of persons and better orientation
- Tuneable White: Variable colour temperature (for night milieu)
- Specific energy demand: 4W/m²

Application Area: 230 m² of Common Mall Area Trondheim; in 2 areas contolled according to availability of natural light

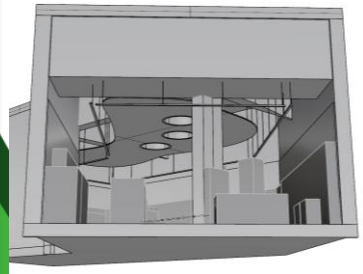
Lighting: Retail Wallwasher Luminaire

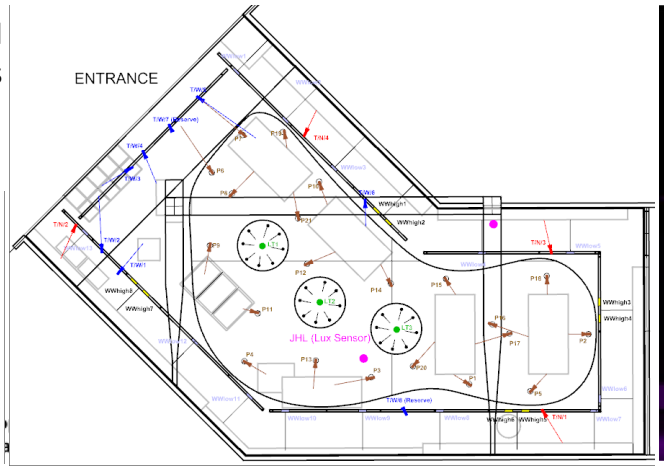


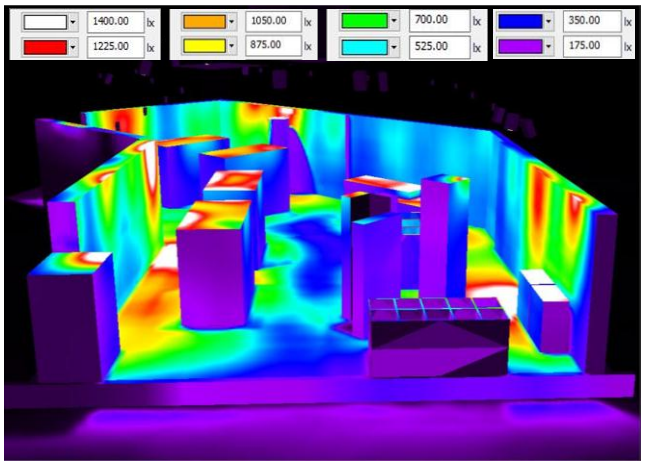
- Application: Wall area with merchandise in shops
- Homogeneous light distribution
- Perfect longitudinal glare protection
- Wide beam angle:
  for examination of merchandise close to wall
- Tuneable white
- High light output: 4800 lm

- Application Area: 85m^2 in wool shop (Trondheim)
- 4 types of artificial LED lighting
- Daylight harvesting by light tubes with integrated artificial light

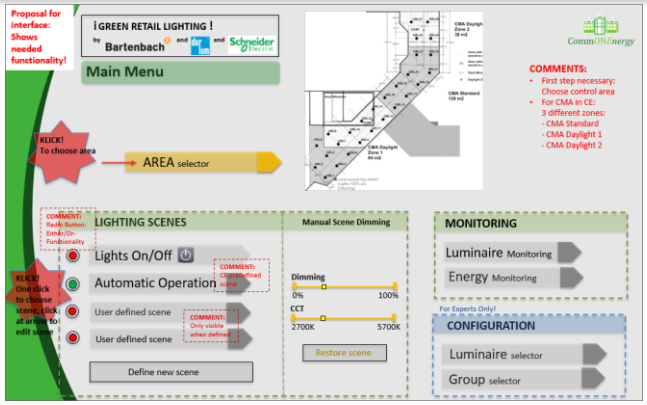
Development: Finished
Manufacturing: in progress

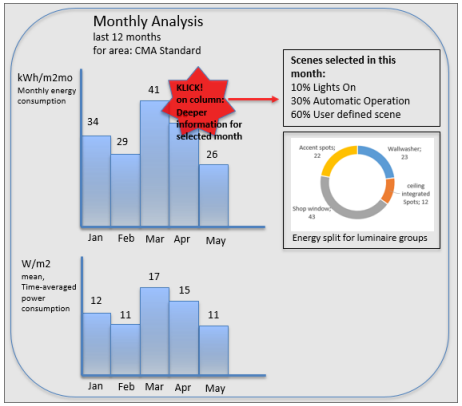






Lighting: Green Lighting Box





Development and application in progress

- Green Lighting Box:
  Independent control system for shops with a connection to iBEMS
- Programmable for complex lighting scenes and lighting time sequences; can organize different areas and luminaire groups
- Several energy monitoring functions, available at the shop.

Energy “savings”
Specific load of shop luminaires due to control strategies with different modes

SHOP								
			OoO	Prep	Bu		Prep	OoO
CASE 0	**ACTUAL STATE**		0 W/m²	39,8 W/m²				0 W/m²
CASE 1	**NEW LUMINAIRES, NO CLO**		0 W/m²	25,3 W/m²				0 W/m²
CASE 2	NEW LUMINAIRES, **CLO**		0 W/m²	22,8 W/m²				0 W/m²
CASE 3	NEW LUMINAIRES, CLO, **Zoning, Op/BU Hours** (En.eff.1)		0 W/m²	12,7 W/m²	18,1 W/m²		12,7 W/m²	0 W/m²
CASE 4	NEW LUMINAIRES, CLO, ZONING, Op/BU Hours, **Night Milieu** (En.eff. 2)		0 W/m²	12,7 W/m²	18,1 W/m²	12,7 W/m²	9,7 W/m²	0 W/m²
CASE 5	NEW LUMINAIRES, CLO, ZONING, Op/BU Hours, Night Milieu, **Daylight-sens. Control,** (En. Eff. 3)	- Daylight Zone	0 W/m²	4,5 W/m²	6,4 W/m²	4,5 W/m²	4,5 W/m²	0 W/m²
		- Non Daylight Zone	0 W/m²	8,2 W/m²	11,7 W/m²	8,2 W/m²	8,2 W/m²	0 W/m²
					DLT, to be applied on these setpoints			
			Example for "Day"					

OoO: Out of Operation | Prep: Preparation Hours | Bu: Business Hours

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HVAC&refrigeration

- Coupling **HVAC+R** system
- **Adaptive** Cabinet Control
- Fully exploit the capabilities of shopping mall overall systems and **iBEMS** to interact with refrigeration plant

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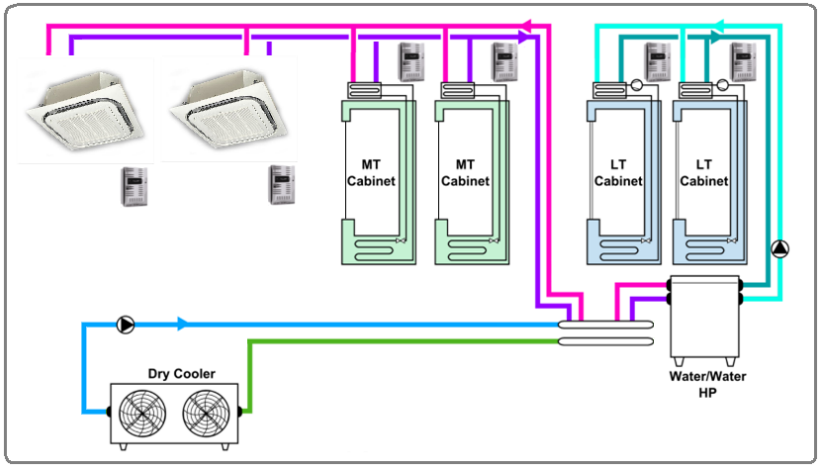
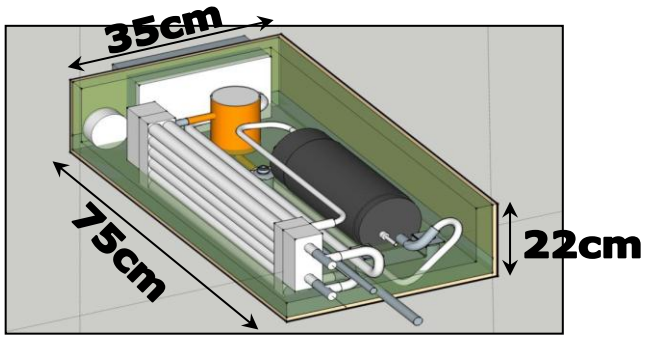
HVAC&refrigeration:

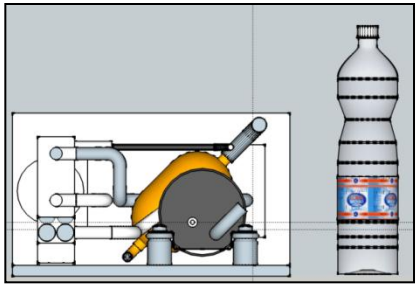
CO_2 Water Loop system





HVAC

Refrigeration



System description:

- Horizontal BLDC inverter driven compressor;
- Water condensed and inverter water cooled.

System advantages:

- **INVERTER AND ELECTRONIC EXPANSION VALVE:** adaptation to changing cooling demand;
- **CHARGE REDUCTION AND FACTORY TEST**: each cabinet is tested in factory;
- **RELIABILITY**: each cabinet has its own unit;
- **CLOSED SHELL FOR THE COMPRESSOR UNIT**: quitness in the store.

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HVAC&refrigeration: Optimized transcritical booster CO_2 system

Traditional solution

Refrige ration + HVAC

Epta solution

EPTA HVAC+R

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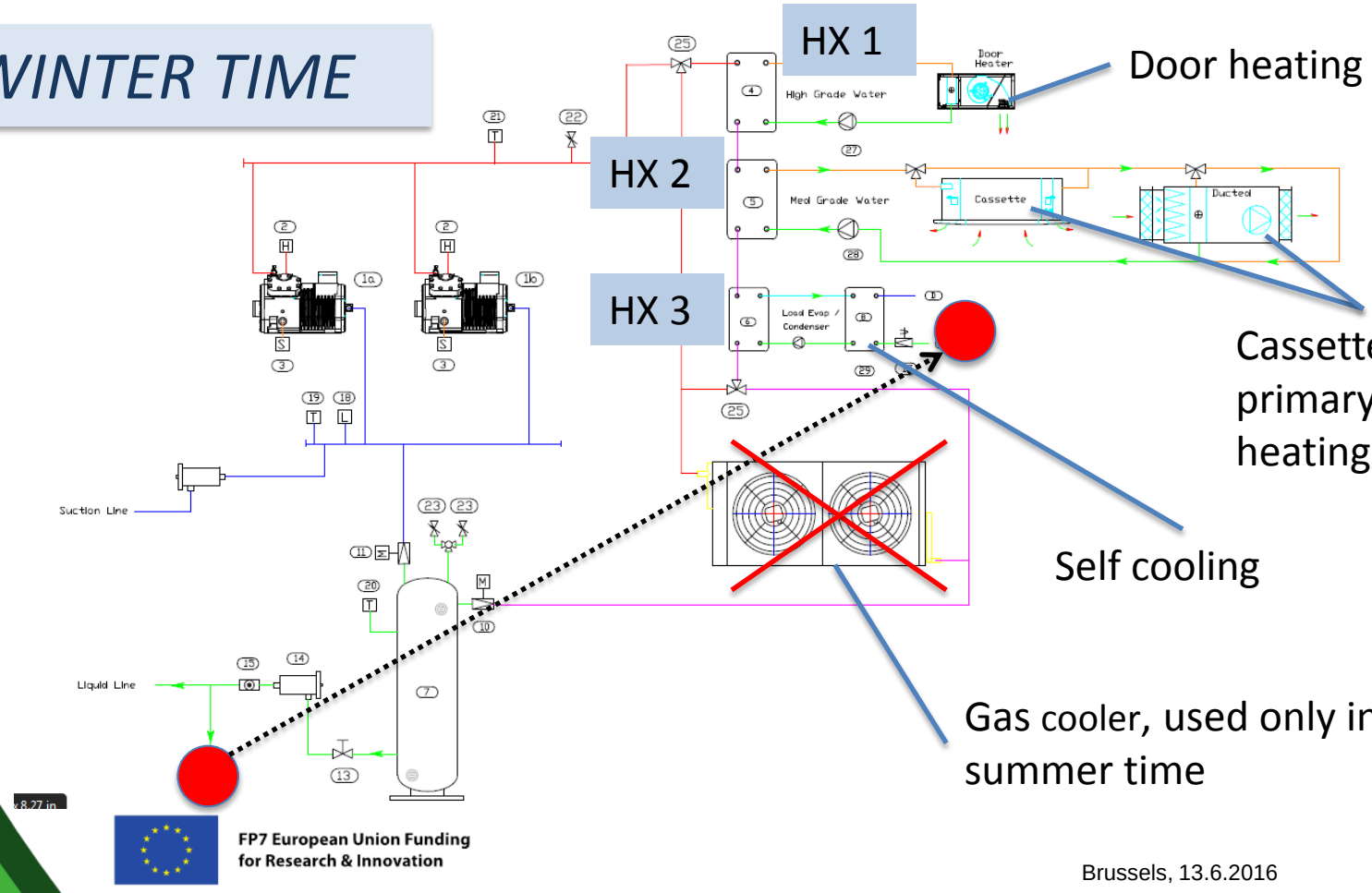
WINTER TIME

Brussels, 13.6.2016

HVAC&refrigeration: Optimized transcritical booster CO_2 system

WINTER TIME



Door heating

Cassette and primary air heating

Self cooling

Gas cooler, used only in summer time

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HVAC&refrigeration: Optimized transcritical booster CO_2 system

WINTER TIME = Full heat recovery

In winter time Optimized transcritical CO_2 plant allows 100% heat recovery to provide store heating without the need of additional heat sources.

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HVAC&refrigeration: Optimized transcritical booster CO_2 system

Traditional solution

Refrige ration + HVAC

Epta solution

EPTA HVAC+R

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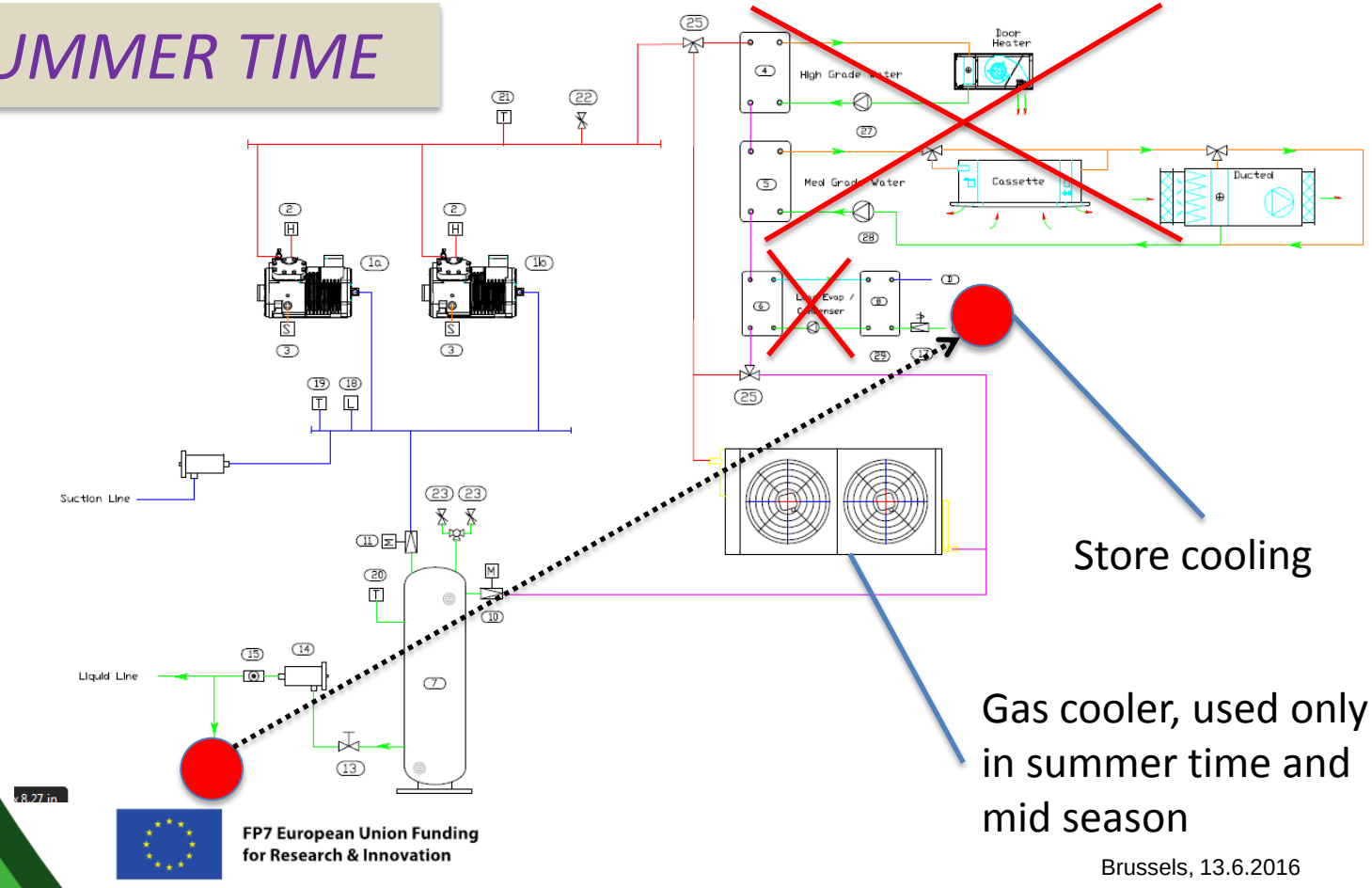
SUMMER TIME

Brussels, 13.6.2016

HVAC&refrigeration: Optimized transcritical booster CO_2 system

SUMMER TIME



Store cooling

Gas cooler, used only in summer time and mid season

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HVAC&refrigeration: Optimized transcritical booster CO_2 system

SUMMER TIME

In summer time the same plant provides the necessary cooling amount for refrigeration and for A/C with parallel compression.

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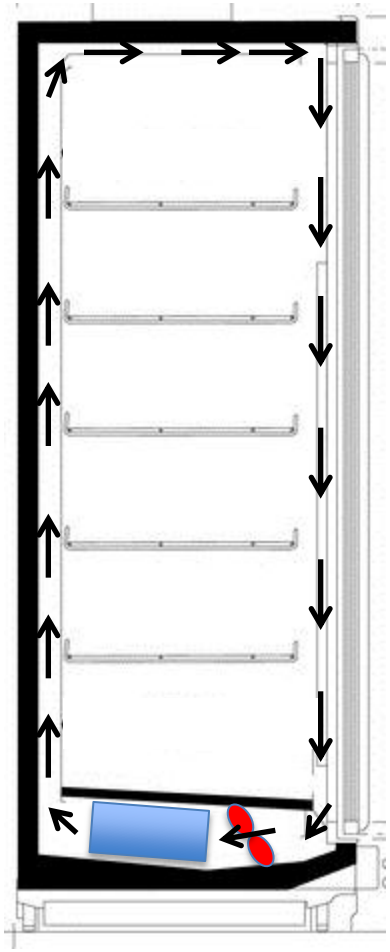
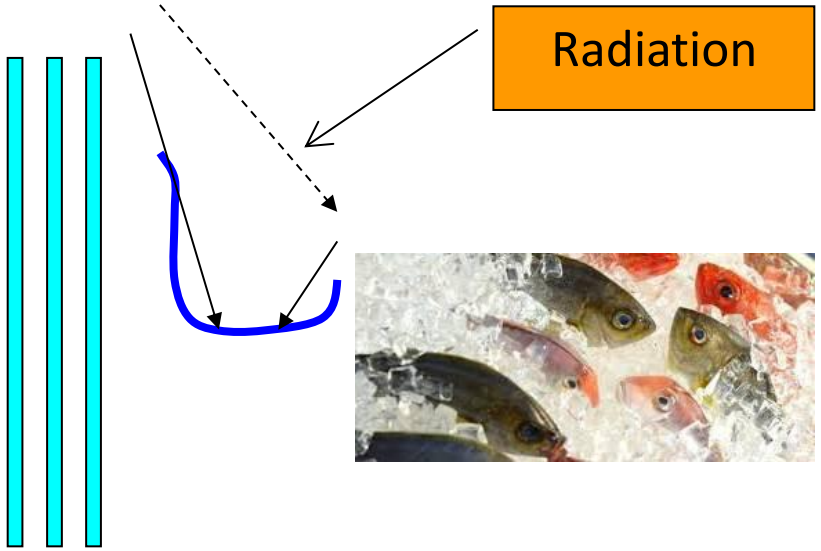
HVAC&refrigeration: adaptive air flow





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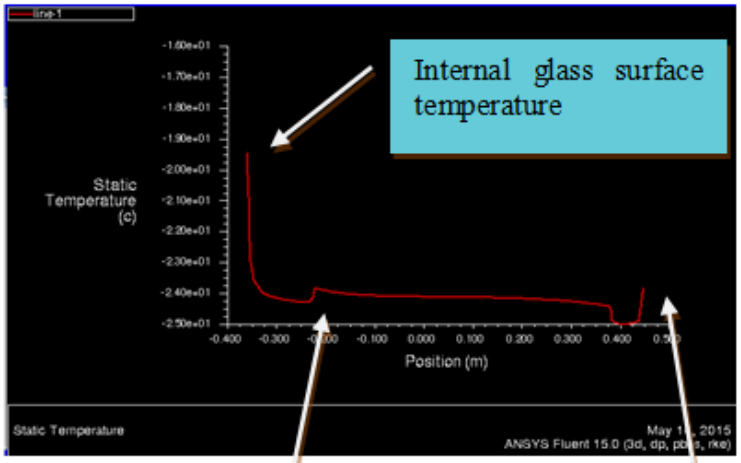
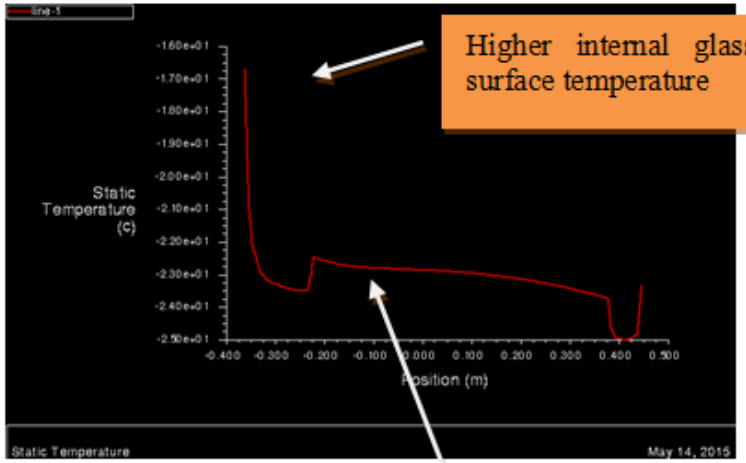
HVAC&refrigeration: adaptive air flow

Air flow reduced in **off-design (field)** condition allows saving energy

Normal air flow



Reduced air flow



front M-pack surface temperature

back wall surface temperature

Higher front pack surface temperature

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HVAC&refrigeration: optimization of thermal zoning

- Interaction between HVAC and refrigerated cabinets
- RDC performance
- HVAC loads
- Thermal comfort for the customer

- Use of closed display cabinets
- Risk of mist formation

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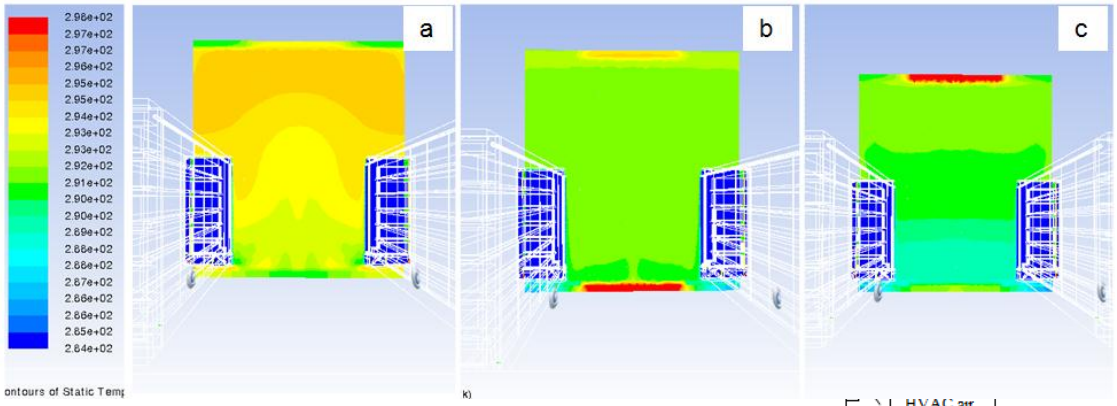
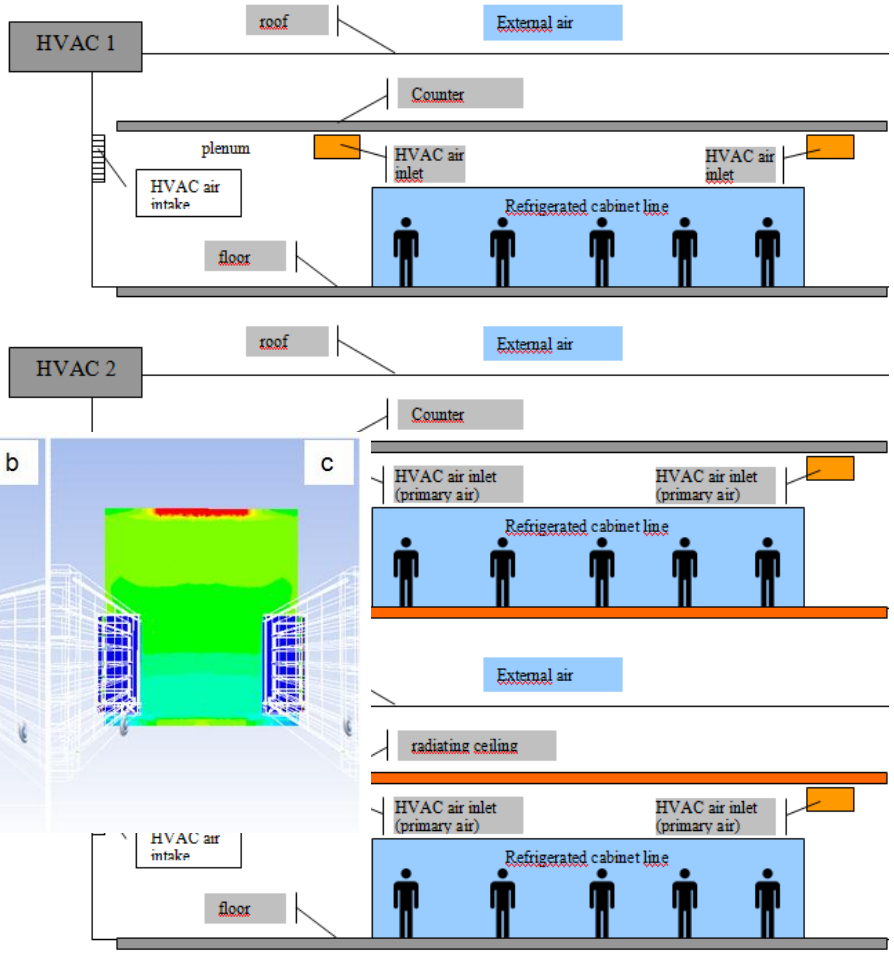
HVAC&refrigeration: optimization of thermal zoning

Radiant panels (floor or ceiling) as an energy saving alternative to full air HVAC





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HVAC&refrigeration: optimization of thermal zoning

LT: Comfort Performance Indicators (winter)

Key Performance Indicator		HVAC 1 pure vented	HVAC 2 radiant floor	HVAC 3 radiant ceiling
Global comfort	PMV [-]	0.12	0.18	-0.02
	PPD [%]	5.30	5.67	5.01
Local comfort	Mean air velocity [m/s]	0.06	0.03	0.03
	Draught Rate (DR)	2.86	0.00	0.00
	Air temperature vertical gradient [K]	7.17	1.47	3.78
	PD – Vertical air temperature differences [%]	59.33	1.10	7.42
	Floor temperature [°C]	17.91	22.50	19.01
	PD – floor temperature [%]	12.84	5.78	10.34
	Radiant temperature asymmetry – cold ceiling [K]	2.55	2.35	5.50
	Radiant temperature asymmetry – cold wall [K]	2.53	1.62	2.25

class A class B class C discomfort

HVAC&refrigeration: optimization of thermal zoning

LT: Comfort Performance Indicators (summer)

Key Performance Indicator		HVAC 1 pure vented	HVAC 2 radiant floor	HVAC 3 radiant ceiling
Global comfort	PMV [-]	1.22	-0.21	0.05
	PPD [%]	36.36	5.88	5.06
Local comfort	Mean air velocity [m/s]	0.05	0.02	0.02
	Draught Rate (DR)	0.00	0.00	0.00
	Air temperature vertical gradient [K]	2.83	4.94	3.95
	PD – Vertical air temperature differences [%]	3.43	17.78	8.48
	Floor temperature [°C]	25.21	18.81	21.93
	PD – floor temperature [%]	6.10	10.76	6.15
	Radiant temperature asymmetry – cold ceiling [K]	3.86	6.94	1.51
	Radiant temperature asymmetry – cold wall [K]	3.41	3.76	3.52

class A class B class C discomfort

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Guidelines on retrofitting of shopping malls

1. IDP process for retrofitting shopping centres
2. Integrative Modelling Environment
3. Optimized building envelope and architecture
4. Lighting
5. Optimization of refrigeration cabinets area layout and technologies
6. Novel energy distribution layout and generation technologies for shopping centres
7. Smart supervision and management of shopping centres
8. Local energy generation, grid interaction and storage
9. Impact assessment

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Integrative Modelling Environment - IME

IME: *WHY*

A numerical model of the whole shopping mall (building + systems) can help to:

- Assess the **building behaviour** and **system performance**;
- Study the **thermal comfort**;
- Develop and test a **comprehensive control** which is able to manage the **whole system**.

Useful during the **design phase** of a new shopping mall or when a **refurbishment** is planned.

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Integrative Modelling Environment - IME

IME: *WHAT*

The IME consists in:

- **Simulation environment** with all the system's parts are implemented;
- Modular structure where each module is a **sub-system**, called ***subdeck;***
- Subdecks are composed by *types* that represent **each component** of the sub-system;
- **Parametric characterization** and **modular structure** allows sensitivity and parametric analysis

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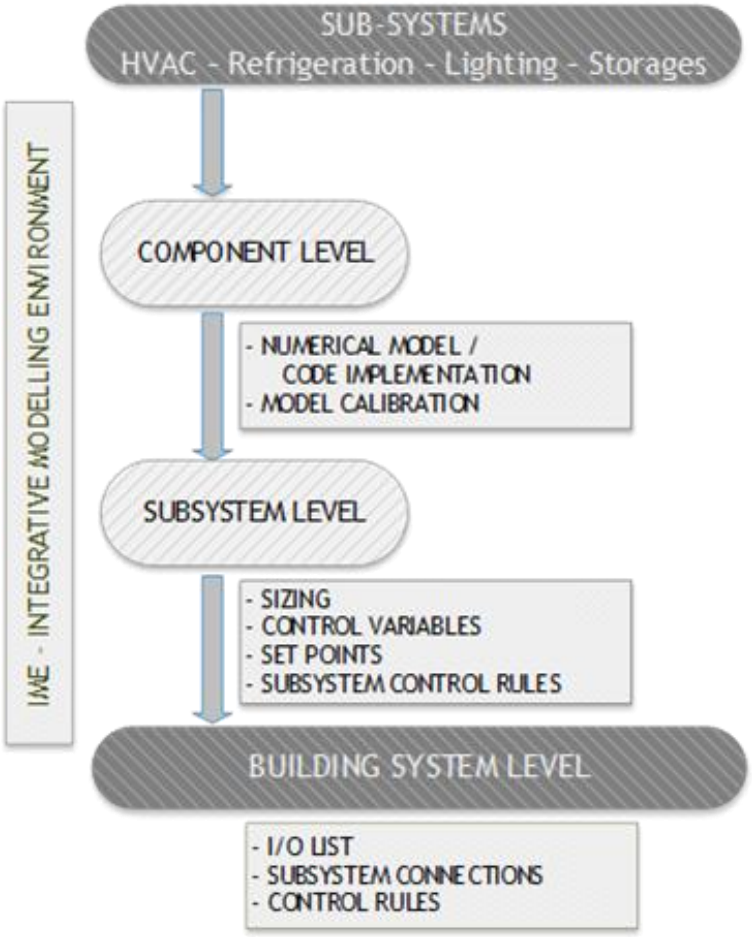
Integrative Modelling Environment - IME

IME: *HOW*

1. Individuation of the **sub-systems**;
2. Definition and modelling of the sub-system‘s **components**;
3. **Sizing** and **internal control** development of each subdeck;
4. **Integration in the whole system** of the single subdecks.



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Integrative Modelling Environment - IME

IME: *List of passive solutions subdecks*

- **Climate adaptive façade** → integrated in the building model itself;
- **Daylighting** → inhouse type;
- **Green wall** → inhouse type;
- **Multifunctional coatings** → set of specific wall's absorptance;
- **Thermal acoustic panel** → included in the wall's thermal features;
- **Ventilative cooling** → studied with TRNFLOW.

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Integrative Modelling Environment - IME

IME: *List of active solutions subdecks*

- **Artificial lighting** → thermal and electric aspects accounted for in the model;
- **Electric storage** → standard types with ad hoc control strategy;
- **Refrigeration system** → inhouse types;
- **Solar thermal system** → standard types;
- **HVAC system** → standard types with ad hoc control strategy;
- **Electric mobility** → at SC level, accounted only as load profile.

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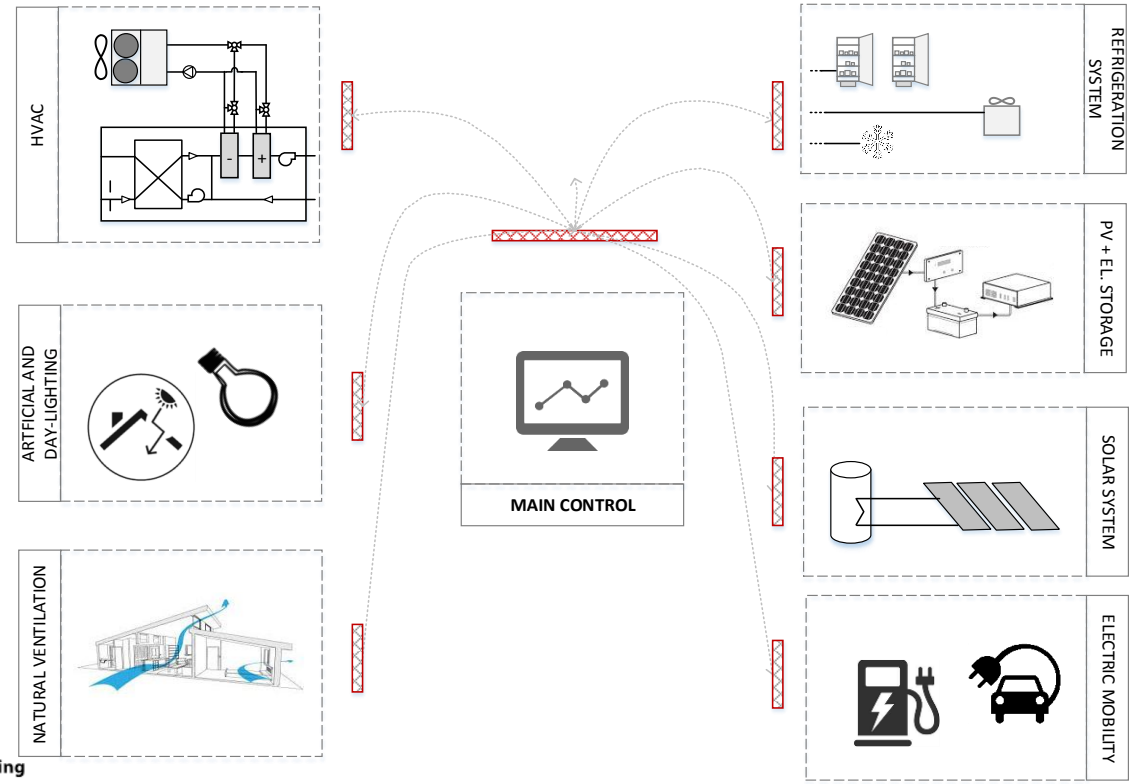
Integrative Modelling Environment - IME

IME: *Control system:* Main control system (iBEMS) that communicates with the single subdecks

same control rules are used in simulations and in the field



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Integrative Modelling Environment - IME

IME: *Outputs*

- **% of discomfort hours** considering the occupied hours;
- **Thermal signature** (base temperature, slope);
- **Energy balance**: lost-gains in different season for the whole building and for final uses;
- **Systems power frequency** to ensure desired IEQ level;
- Fraction of occupied time **lighting comfort** achieved;
- **Energy consumption** by **final uses, final energy and primary energy**;
- **Efficiencies/performance** of the specific system;
- **Production of RES** and amount of self consumption.

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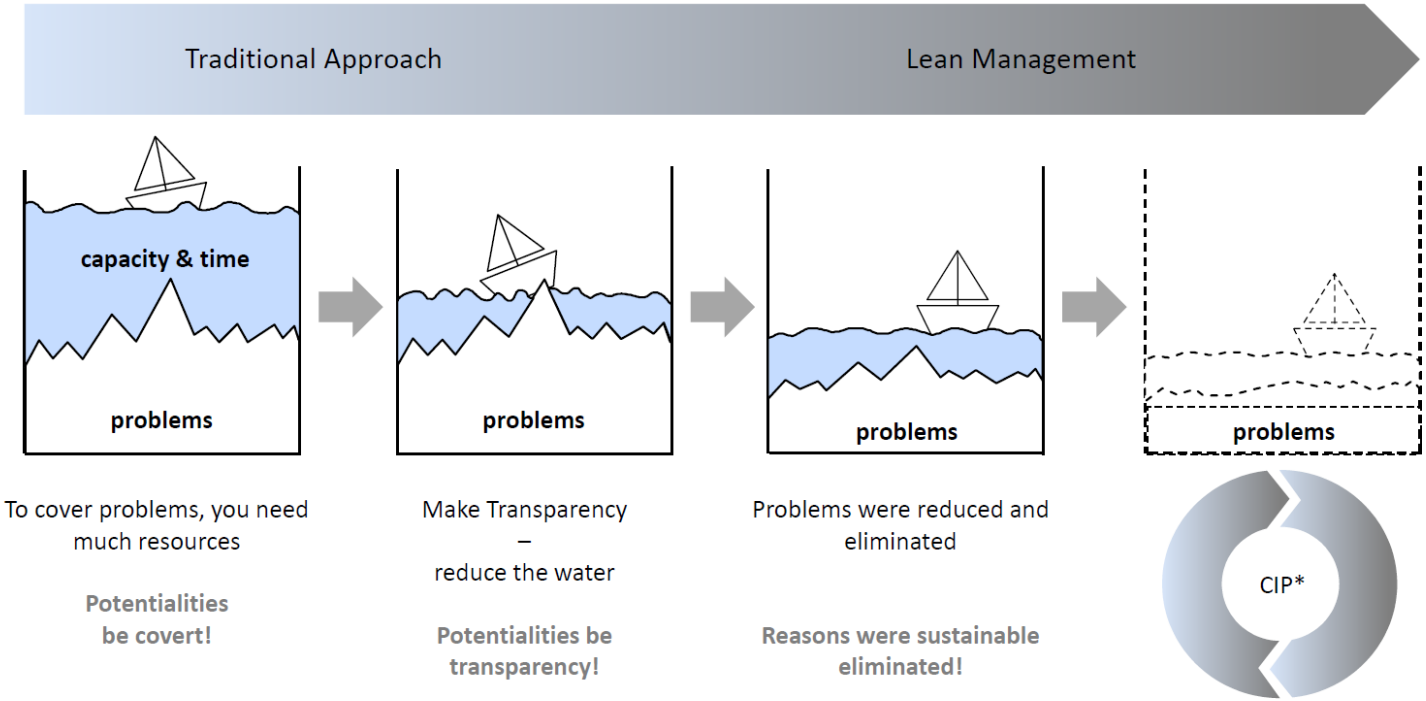
DS CONSULTING
PROCESS & ORGANIZATION

The Lean-Approach

- Regular problems were overloaded by an excessive input of resources
  Lean Management helps to identify the reason and eliminated them



*CIP = continous improvement process

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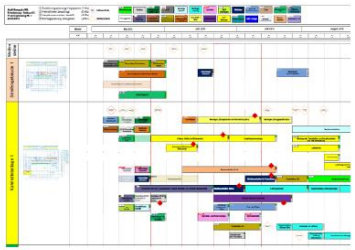
DS CONSULTING
PROCESS & ORGANIZATION

The Lean-Approach

- An integrated process system

	1 Overall process analysis	2 Process planning	3 Detailed planning
Elements			
Content / Added value	▪ Development of the overall process with all involved parties ▪ Planning „reverse" from the end of the process ▪ Early detection and resolving conflicts in the planning phase ▪ Optimized process ▪ Link flow and logistics ➡ Early recognition of problems ➡ Common understanding of the overall project	▪ Structuring based on defined work areas ▪ Milestone management as a communication medium ▪ Clocking of the processes for planning and execution ▪ Definition of stability criteria with traffic light system ➡ Reduced obstacles ➡ Monatly new rolling	▪ Planning and control of the execution on daily basis for 4 weeks ▪ Evaluation and tracking of necessary inputs and obstacles ▪ Process optimization of all processes ▪ Control information flow ➡ Speed up without extra costs ➡ Weekly rolling and daily contol

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The Lean-Approach: Modena demo-case

- Implementation of Lean Construction Management for the project in Modena
  - Training of participants on the basis of a simulation
  - Waste walk on the warehouse
  - Coaching of the LCM tools
  - Introduction of an overall process analysis
  - Implementation and optimization of the process planning
  - Implementation of an action list
  - Definition of the planning card
  - Update process planning and action list

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intelligent Building Energy Management System – iBEMS

The iBEMS incorporates:

- Use of open communication protocols for data exchange with all the various systems installed in shopping malls and with third parts using open protocols (e.g. Webservices)
- Control algorithms which have been developed and verified with simulation tools in order to maximize the Energy saving while improving the comfort.
- Advanced graphical environment for showing the measurements collected through sensors and meters defined in the Monitoring and Verification Plan.
- A powerful Reporting Tool that allows to verify if the system is obtaining the expected results and potentially continuously improve the control rules for adapting to the real system.

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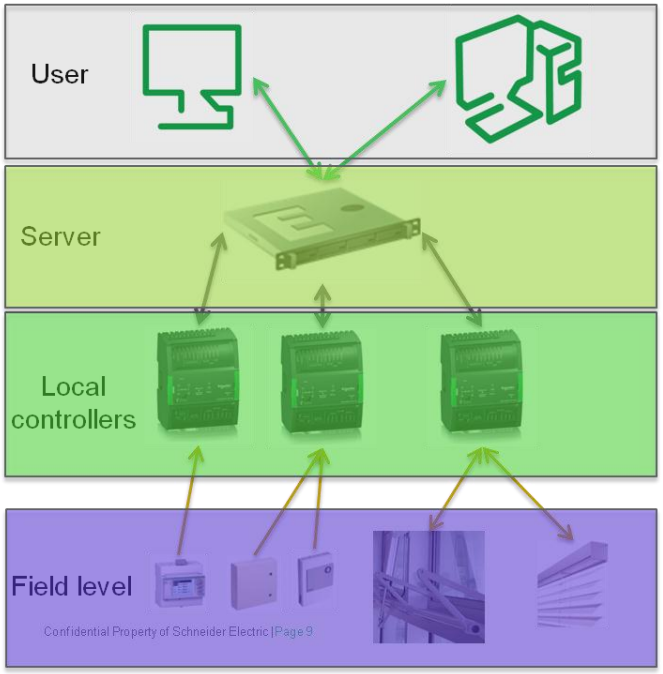
intelligent Building Energy Management System – iBEMS

For the **demo cases**, the iBEMS consists of different systems connected to the local controllers using the available open protocols.

The local controllers perform the logging of the required parameters and are responsible for the transfer of information and commands from the systems to the server and vice versa.

Finally the user can overview and override the operation of the system from a dedicated PC in the control rule or any browser using the correct credentials.

Also the system automatically informs dedicated users in case of alarms that are their responsibility to overview.



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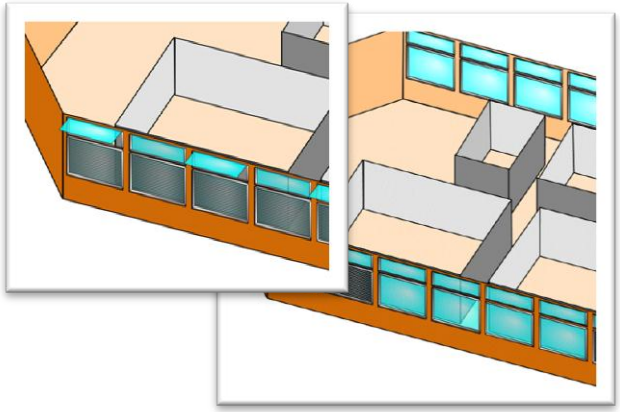
intelligent Building Energy Management System – iBEMS

As aforementioned in the iBEMS run control algorithms (verified in simulation environment) which can applied in several systems connected to it.

Example:

- Shading system
- Natural ventilation system
- HVAC system
- Lighting



Different values affect the operation of the systems in parallel. Since the control is performed in higher level using the iBEMS and the commands are sent to all the systems, energy saving is maximized.

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intelligent Building Energy Management System – iBEMS

The iBEMS integrates advanced graphics showing the areas of interest with the installed equipment and its working conditions.

As an example, for the artificial lights connected to the iBEMS, the user can overview their performance, the power demand as well as the energy consumption.

In case it is required, dedicated users can adjust the operation of the artificial lights.

Similarly, graphics for shading systems have been developed with the possibility to adjust their positioning if required.

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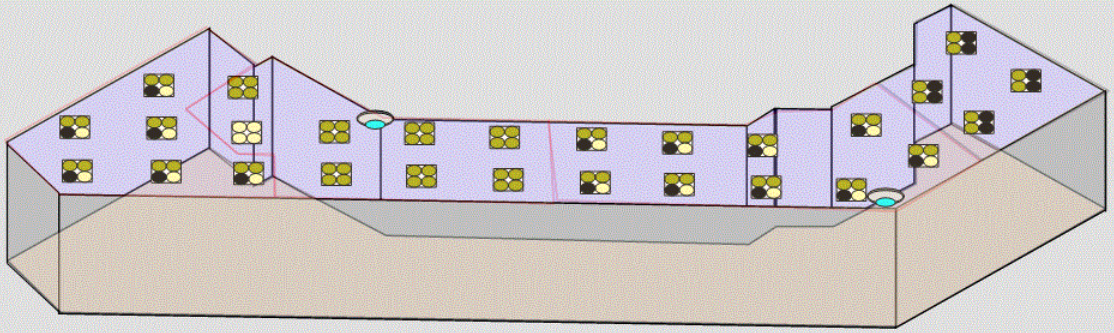
Home
Demo Bldgs.
Weather St
Art. Lights
MicroGrid
Lamellas
Ventilation
Refrigeration
Th. Storage
Power St
Hydrogen St



100 % Dimming
75 % Dimming
50 % Dimming
25 % Dimming
0 % Dimming

Selected zone
CMA Daylight 2

Lighting scenes

- Lights On/ Off
- Automatic operation
- User scene 1

Manual scene dimming

Dimming
0 100
CCT
2700 5000
Activate override

MONITORING

- Luminaire monitoring
- Energy monitoring

Schneider Electric

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EURAC research

Continuous Commissioning platform

Definition of KPIs in commercial building based on:

- 5 groups to evaluate building performances:
  - ❑ *Heating and Cooling system*
  - ❑ *Electric system*
  - ❑ *Mechanical ventilation*
  - ❑ *Rerigeration cabinet and system*
  - ❑ *Economic index*

- together with IEQ aspects:
  - ❑ *Index of thermal comfort*
  - ❑ *Index of visual comfort*
  - ❑ *Index of CO_2 level*

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EURAC research

Continuous Commissioning platform

TOP-DOWN approach

FAULT DETECTION

Connected with the **BMS and weather station**

Higher relevance of Indicator (Comfort + Energy consumption)

C.C. platform

Based on **Monitoring Data**

Understandable for Energy manager

Connected with the **IPMVP procedure**

Comparison of Building performance

1) with other similar buildings
2) with different periods
3) Before and after the retrofitting

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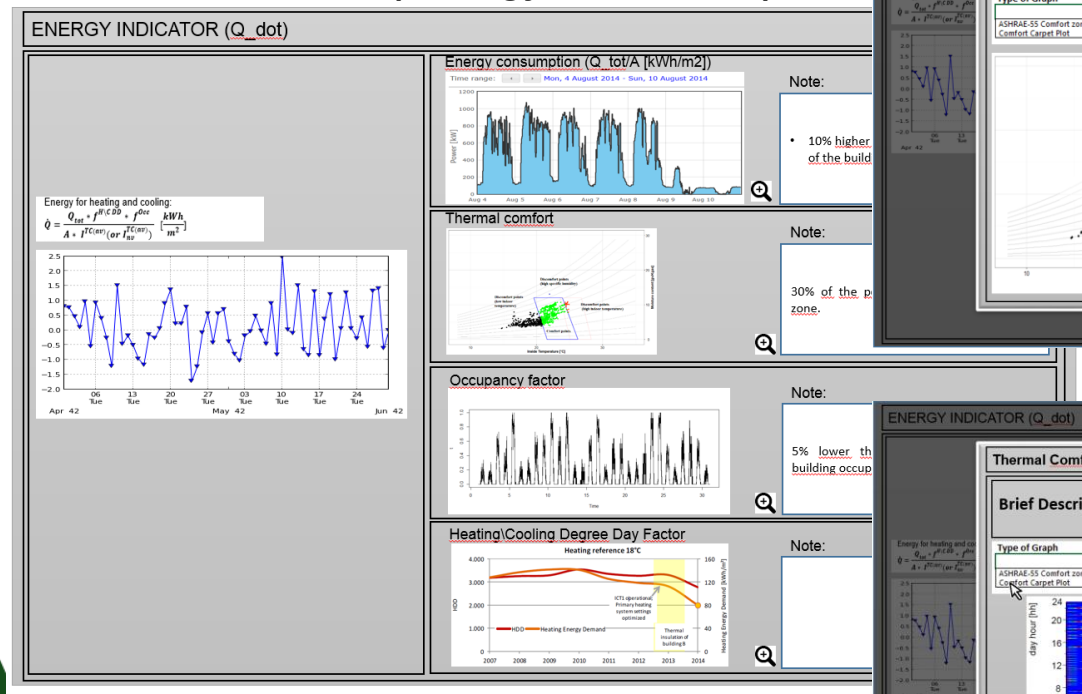
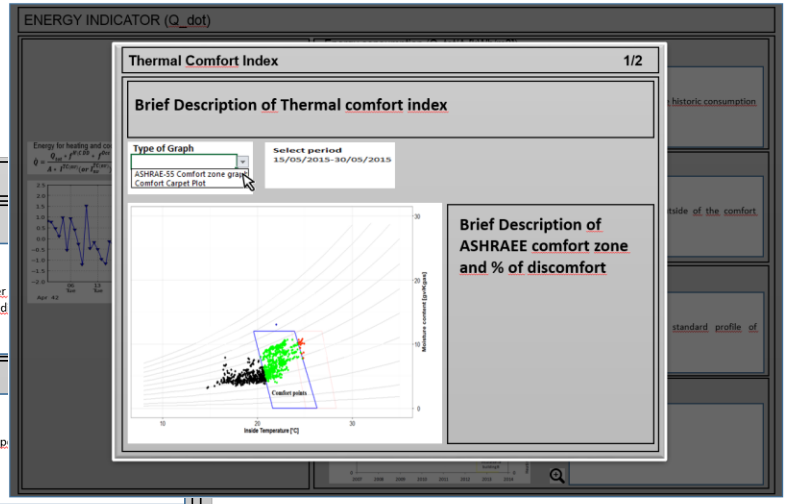
EURAC research

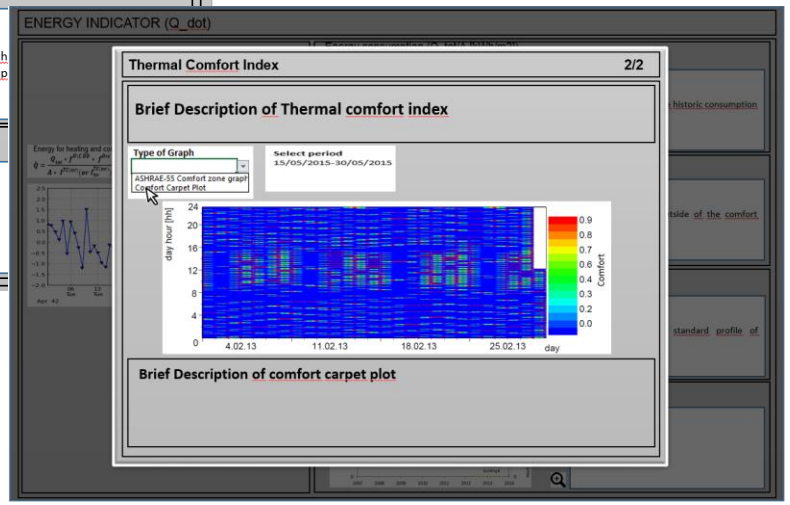
Continuous Commissioning platform

Overall indicator (energy + comfort)



Single indicator (energy or comfort)





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Policy recommendation to secure innovation

EXPLOITATION

→ Common clear Key Performance Indicators to assess projects success
- ❖ energy/comfort performances
- ❖ economic performances and business opportunities: leveraged private investments, market penetration of results …
- ❖ policy maker awareness

→ Reliable calculation or measurement method for KPIs

→ Standardisation for hugest replicability

→ Common open access (i) database for quantitative performance results (ii) repository for technology solutions

→ Business plan as soon as possible

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Policy recommendation to secure innovation

TRAINING AND DISSEMINATION

Specific training to promote new jobs or transformation of industrial and handcraft activities to answer the demand of market trends

Dissemination strategies and actions that assign a new function to shopping centers by raising awareness on energy efficiency issues

Lean pool for craftsmen

Training workshops with practitioners

Shopping malls **sustainability award**

Guidelines on how to approach the energy-efficient renovation of SC

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Thank you for your kind attention!

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