S4ECoB
SOUNDS FOR ENERGY CONTROL OF BUILDINGS

Sounds for Energy Control of Buildings
WP5 Optimisation of BEM systems

Final Review meeting

08 June 2015

D'APPOLONIA consulting, design, operation & maintenance engineering
Fraunhofer IDMT
IMMS
Solintel
AIT AUSTRIAN INSTITUTE OF TECHNOLOGY
SEA
CÓRIO

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Objectives

Previous reporting period

- ❑ Create Building Energy Simulation (BES) models, undertake energy audits, Analyse BMS data (T5.1)
- ❑ Use BES models to develop control strategies for the HVAC systems based on occupancy (T5.2)

Final Reporting period

- ❑ Finalise control strategies based on operational data, define baseline and verification of the BEM performance (T5.3)
- ❑ Quantification and of the BEM performance , via multiparameter cost benefit analysis as well as sensitivity analysis . (T5.4)
- ❑ Web-Monitoring system for BEMO performance (T5.5)

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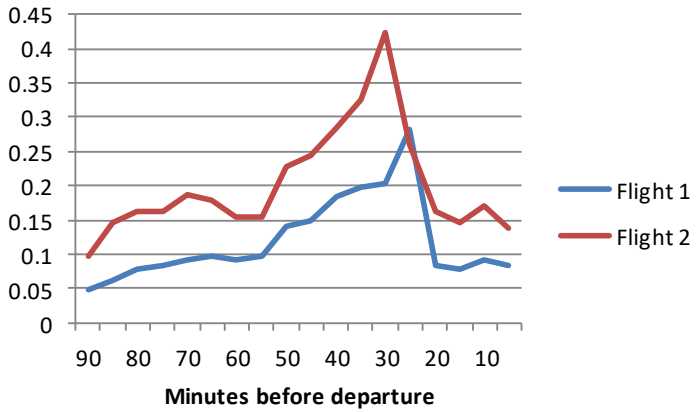
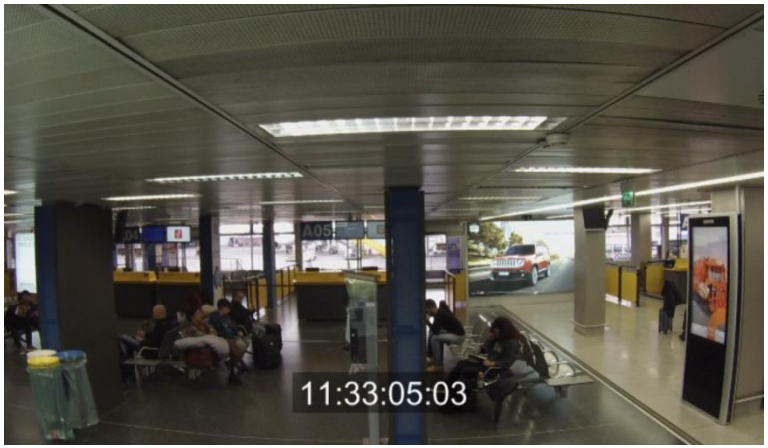
T5.3 Linate Airport - Occupancy Estimation





Mins	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5
% total	7.34%	10.49%	12.00%	12.36%	13.93%	13.87%	12.30%	12.65%	18.42%	19.59%	23.38%	26.12%	31.35%	27.09%	12.36%	11.19%	13.11%	11.14%
People	11	16	18	19	21	21	18	19	28	29	35	39	47	41	19	17	20	17

Time series estimation for a flight with 150 passengers boarding.

1. Roanes-Lozano, E et el.. An accelerated-time simulation of departing passengers' flow in airport terminals. Mathematics and Computers in Simulation 67, 163–172 (2004).

08.06.15

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T5.3 Linate Airport - Occupancy profile using flight schedule

Airport	Year	Flight date	Gate	Pax Tot	Block off time	Scheduled time	Clearance Time
LIN	2014	01/07/2014	A01	46	0637	0640	0640
LIN	2014	01/07/2014	A01	58	0729	0725	0725
LIN	2014	01/07/2014	A02	130	0710	0655	0655
LIN	2014	01/07/2014	A02	68	0820	0820	0820
LIN	2014	01/07/2014	A02	80	1125	1125	1125
LIN	2014	01/07/2014	A02	148	1522	1515	1515
LIN	2014	01/07/2014	A02	58	1728	1725	1725
LIN	2014	01/07/2014	A02	119	1838	1820	1820
LIN	2014	01/07/2014	A02	86	2101	2105	2105
LIN	2014	01/07/2014	A03	139	0656	0655	0655
LIN	2014	01/07/2014	A03	92	0851	0855	0855
LIN	2014	01/07/2014	A03	137	1034	1035	1035
LIN	2014	01/07/2014	A03	67	1205	1205	1205
LIN	2014	01/07/2014	A03	143	1341	1340	1340
LIN	2014	01/07/2014	A03	131	1830	1830	1830
LIN	2014	01/07/2014	A03	78	2155	2155	2155
LIN	2014	01/07/2014	A04	93	0627	0630	0630
LIN	2014	01/07/2014	A04	131	0716	0715	0715
LIN	2014	01/07/2014	A04	150	1205	1155	1155
LIN	2014	01/07/2014	A04	83	1246	1255	1255
LIN	2014	01/07/2014	A04	71	1529	1530	1530
LIN	2014	01/07/2014	A04	115	1730	1730	1730
LIN	2014	01/07/2014	A04	157	1840	1835	1835
LIN	2014	01/07/2014	A04	129	2141	2130	2130

		Gate							
		# of people							
Date	Time	1	2	3	4	5	6	7	8
01/07/2014	04:50	0	0	0	0	0	0	0	0
01/07/2014	04:55	0	0	0	0	0	0	0	0
01/07/2014	05:00	0	0	0	6	0	0	0	0
01/07/2014	05:05	0	0	0	8	0	0	8	0
01/07/2014	05:10	3	0	0	10	0	0	13	0
01/07/2014	05:15	5	0	0	10	0	0	14	0
01/07/2014	05:20	5	0	0	12	0	0	14	0
01/07/2014	05:25	5	8	9	12	3	0	17	0
01/07/2014	05:30	5	12	13	10	4	9	17	10
01/07/2014	05:35	5	14	15	11	5	14	14	14
01/07/2014	05:40	5	14	15	15	5	16	16	17
01/07/2014	05:45	5	16	17	24	5	16	30	17
01/07/2014	05:50	7	16	17	31	5	18	34	20
01/07/2014	05:55	12	14	15	36	5	18	41	20
01/07/2014	06:00	14	15	16	41	5	16	45	17
01/07/2014	06:05	17	21	23	39	7	17	53	18
01/07/2014	06:10	19	23	23	27	7	23	48	25
01/07/2014	06:15	19	27	29	23	9	25	28	26
01/07/2014	06:20	13	31	32	26	10	31	28	32
01/07/2014	06:25	11	36	39	31	12	34	35	36

- Flight schedule fed into program
- Output 5 minute profile for every gate
- Surrounding areas can also be estimated

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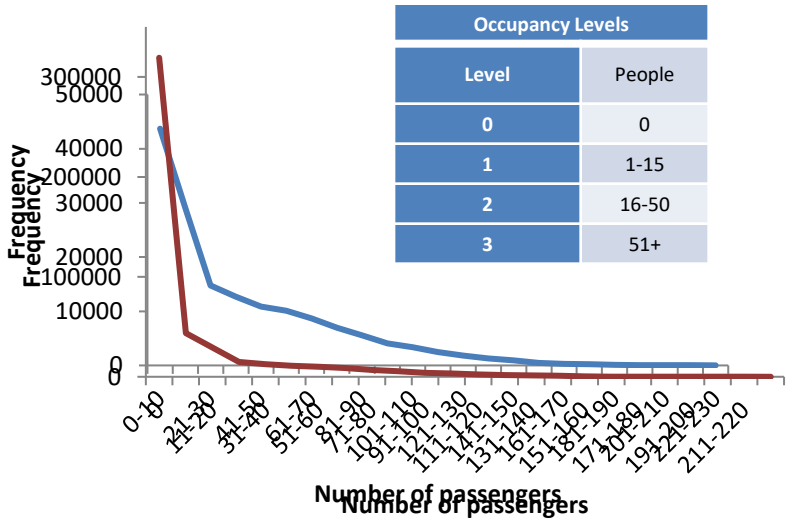
T5.3 Linate Airport - Occupancy Estimation

- 5 minute occupancy profile used to create frequency distribution
- 74% of time gates not occupied
- Occupied periods focused on 3 levels created to maximise applicability with acoustic detection system



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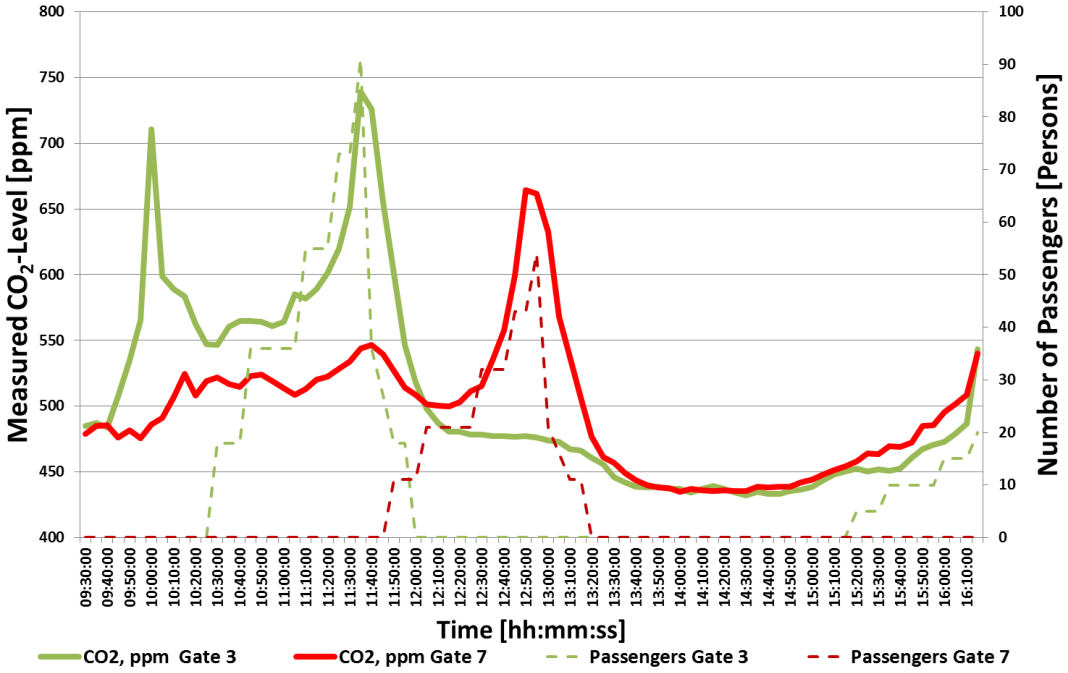
T5.3 Linate Airport - CO_2 Measurements

- 500 – 1400 litres per second ventilation rate
- Peaks correspond with departures
- Potential for flow rate/fresh air reductions



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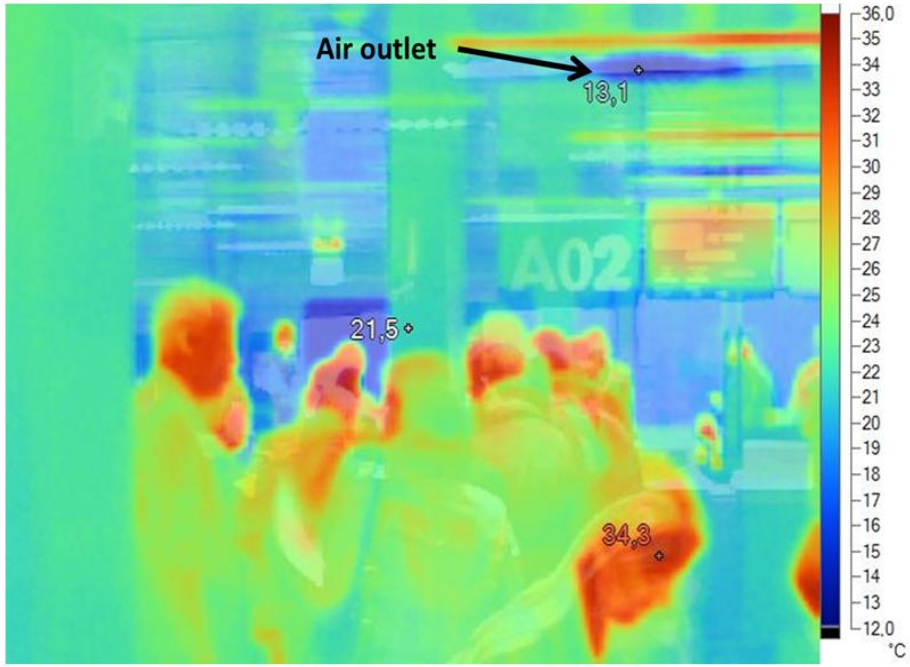
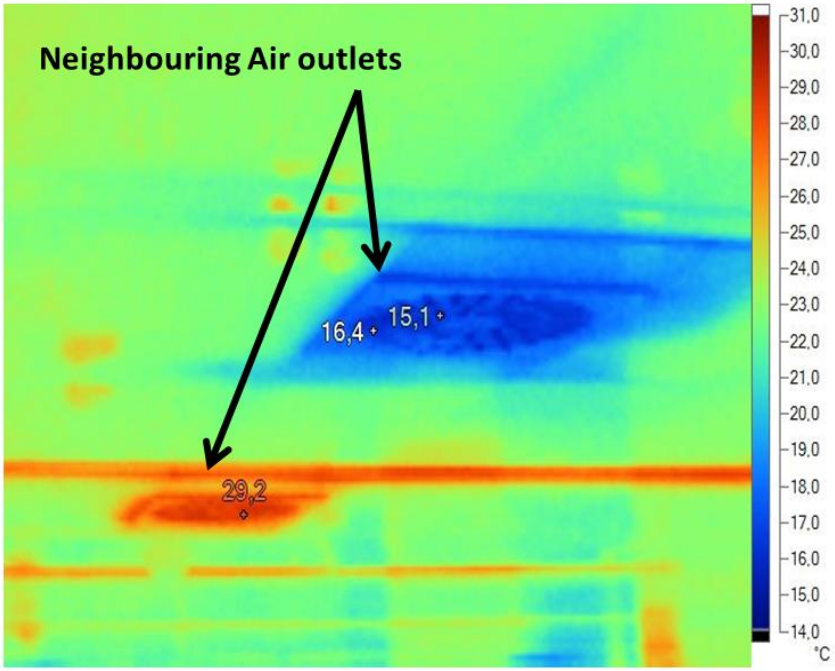
T5.3 Linate Airport – System validation





- VAV boxes drift out of sync and work against each other

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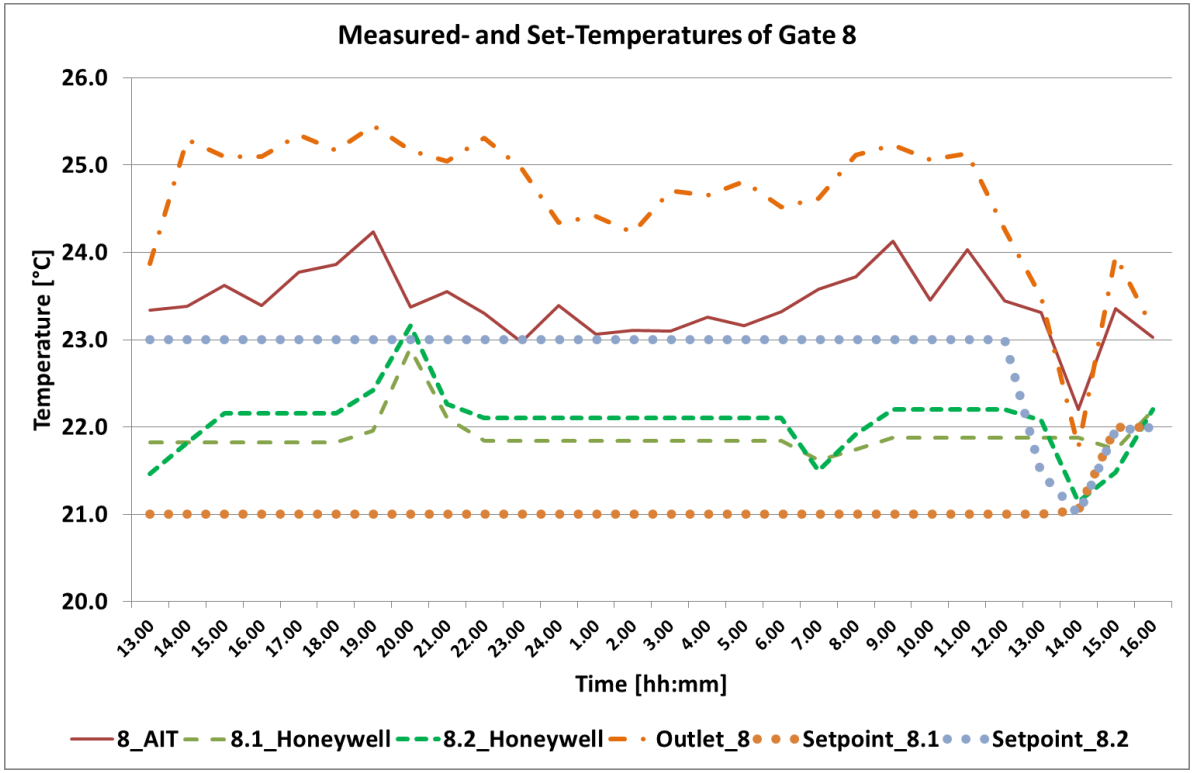
T5.3 Linate Airport – System validation

- Calibrated temperature sensors installed and compared with BMS data
- Both set points adjusted to 22°C at 12pm on the second day
- System began to operate in line with expectations



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T5.3 Linate Airport – Control Strategy

	June			December			
	Hot Flow	Cold Flow	Flow Temp	Hot Flow	Cold Flow	Flow Temp	Fresh Air
Occupancy Level	m^3/hr	m^3/hr	°C	m^3/hr	m^3/hr	°C	m^3/hr
0	150	200	21	1500	0	32	0
1	150	300	19	1000	200	29	450
2	300	1200	16	1200	300	28	1500
3	400	2000	15	1900	500	28	2400

Occupancy Levels	
Level	People
0	0
1	1-15
2	16-50
3	51+

- Fewer occupants = reduced flow rates, increased air recirculation, higher supply temperatures

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T5.4 Linate Airport – Sensitivity Analysis

	Energy Consumption relative to Baseline [%]									
	Cooling Season					Heating Season				
	Q_Heat	Q_Cool	Q_Preheat	Q_Fan	**Q_Total**	Q_Heat	Q_Cool	Q_Preheat	Q_Fan	**Q_Total**
Baseline (Optimal Control)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Better building envelope	123%	87%	99%	100%	93%	78%	246%	94%	95%	94%
Worse building envelope	95%	127%	117%	113%	121%	152%	22%	150%	139%	143%
Higher infiltration	103%	100%	97%	101%	100%	103%	70%	100%	100%	100%
Lower infiltration	104%	99%	101%	102%	100%	99%	105%	99%	99%	99%
Higher OCG	90%	108%	91%	102%	105%	97%	115%	98%	99%	99%
Lower OCG	112%	98%	98%	103%	100%	100%	55%	95%	96%	96%
Higher LG	91%	105%	92%	101%	103%	96%	107%	97%	97%	97%
Lower LG	108%	97%	101%	101%	99%	102%	81%	99%	99%	99%
Higher Recirculation (0.75)	101%	92%	8%	100%	94%	100%	100%	40%	100%	82%
Lower Recirculation (0.25)	98%	107%	254%	101%	106%	100%	93%	158%	99%	117%
Extreme weather	103%	100%	166%	101%	101%	100%	86%	98%	98%	98%

- Adjustment of influencial data. Envelope data was obtained from SEA based on standards at time of construction

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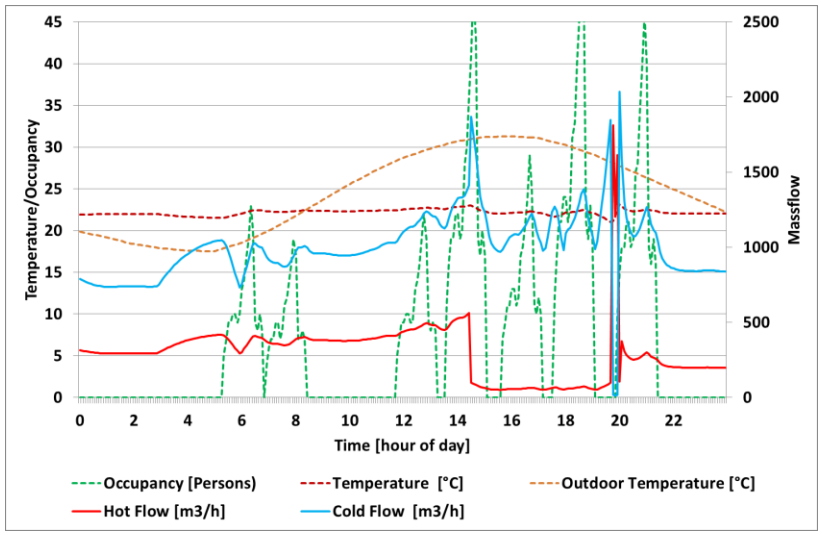
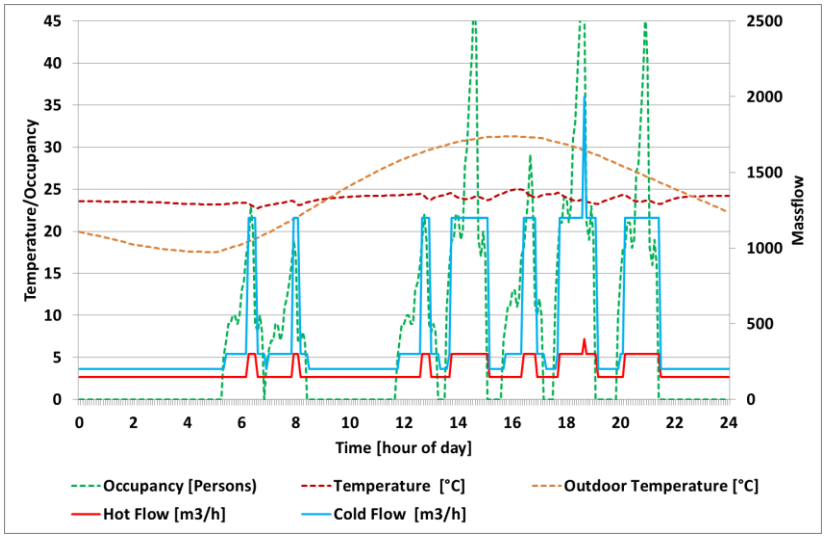
T5.3 Linate Airport – Simulation results

Baseline



Occupancy Controled



- Simulated Mass flow, Occupancy and Temperature at Gate 5 on June 12
- Cooling correlated strongly with occupancy

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T5.3 Linate Airport – Simulation results

- Reduction of Cooling in the Heating Season
- Reduction of Heating in the Cooling Season
- Reduction of overall Ventilation
- On average around 60 – 70 % saving estimated

		Baseline June	Occupancy control June	Baseline December	Occupancy control December
		MWh	MWh	MWh	MWh
Cooling Energy		55.5	14.4	4.3	1
Heating Energy	Main coil	8.5	2.5	42.4	11.5
	Pre-Heat	0.5	0.01	25.7	2.1
Fan Energy		1.1	0.3	12.7	12.7
Total		424.3	123.1	418.6	234.4

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T5.4 – Cost Benefit Analysis

Group	Components	Capital Cost
Equipment	8-channel Microphone array incl. housing (3 pieces, 700 € each)	2,100.00 €
	Audio processing unit	522.00 €
	BEMO Server	2,250.00 €
	Installation Equipment	500.00 €
Personal Cost	Installation & Coordination	2,000.00 €
	Programming	10,000.00 €
Prestudy	Calibration	30,000.00 €
	Total	47,372,00 €

Parameter	Unit	
Period T	[a]	10
Interest rate	[%]	4
Annuity factor	[-]	0.123
Energy price inflation	[%/a]	3
Annuity factor for energy prices	[-]	1.14
Energy price - heat	[€/kWh]	0.038
Energy price - electricity	[€/kWh]	0.11

- Isolating energy consumption data for project area difficult due to lack of detailed metering
- Simulation results for baseline and occupancy control combined with costs of energy and the cost of the system to determine estimate of potential Cost Benefit

Type	Unit	Energy savings Gas	Unit	CO_2 emission saved
Heat	kWh	586,901	ton CO_2e	148
Electricity		52,662		13
Total		639,563		161

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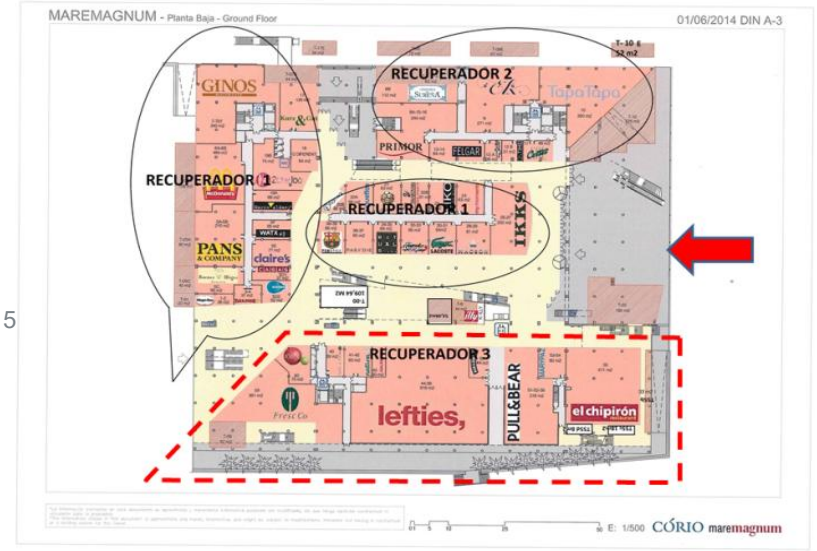
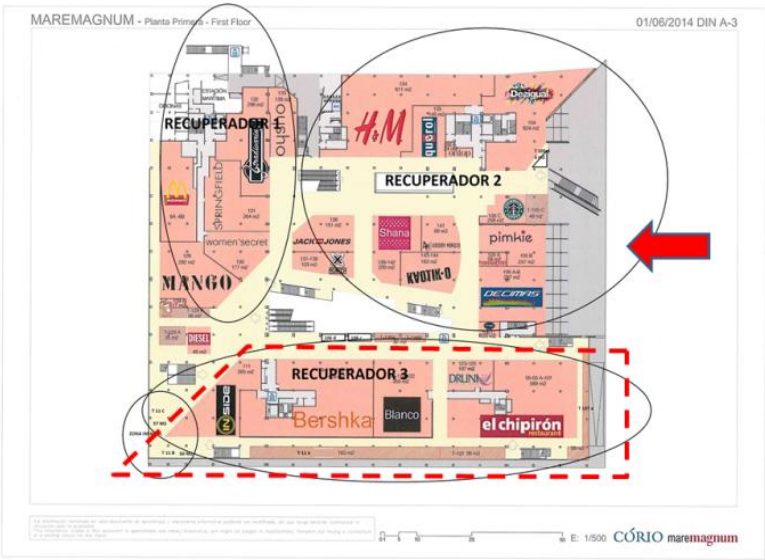
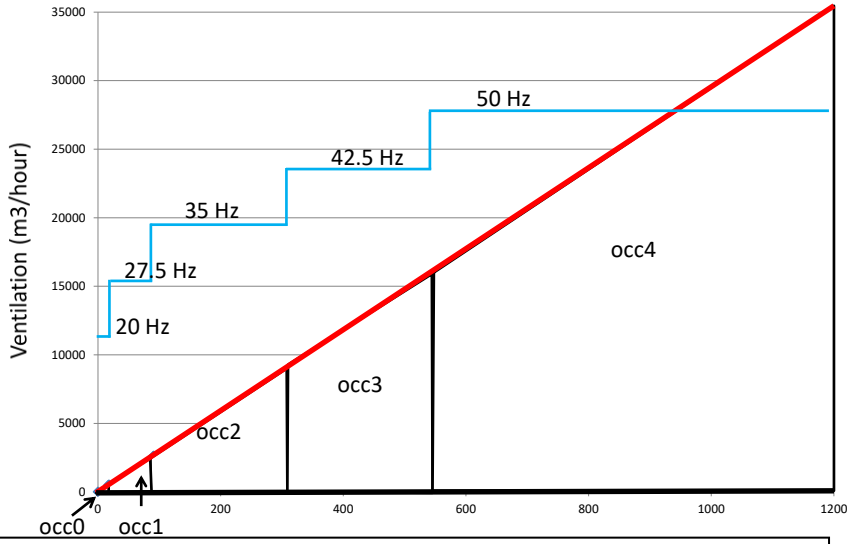
T5.3 Maremagnum – Ventilation system

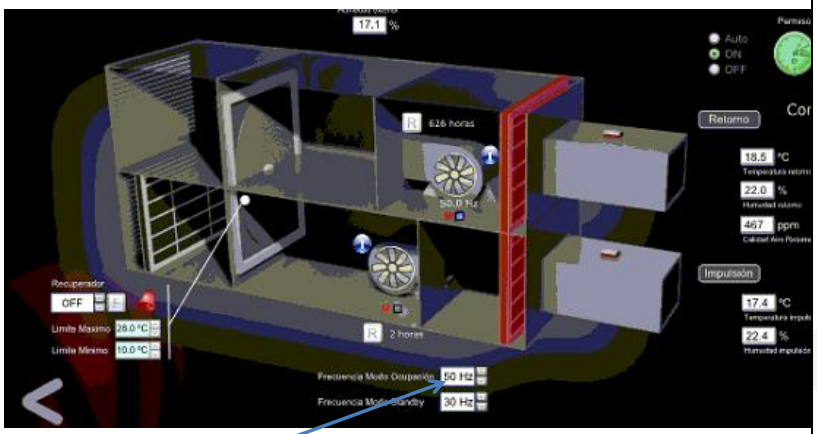
- Maremagnum shopping centre
  - In deliverable D5.1, two main systems of Maremagnum shopping mall were simulated and optimised from a theoretical point of view: **the water loop heat pump system** and the **lighting system**.
  - During the deployment phase (WP6), it was concluded that the theoretical optimisations presented in D5.1 for Maremagnum were not feasible. The reasons will be properly explained in WP6 deliverables.
  - An alternative strategy was needed to integrate the S4ECoB system and save energy in this shopping mall, and **the ventilation system** was chosen now .



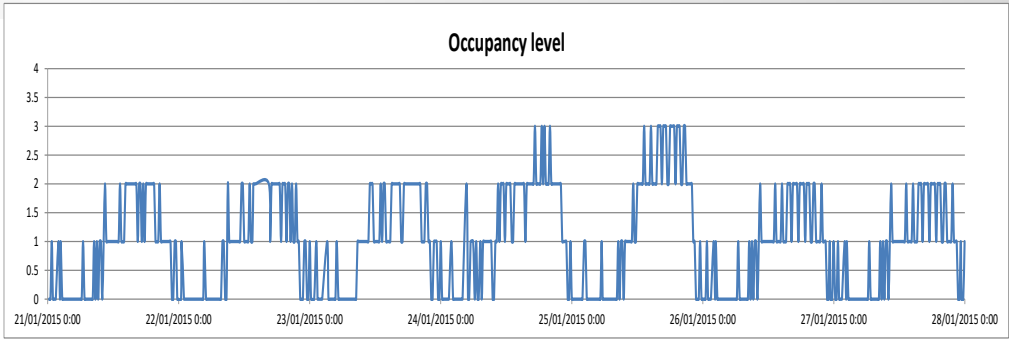


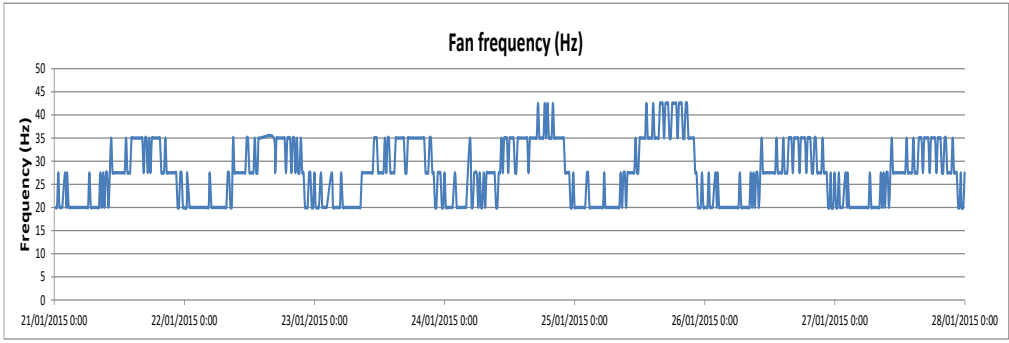
T5.3 Maremagnum – Ventilation system

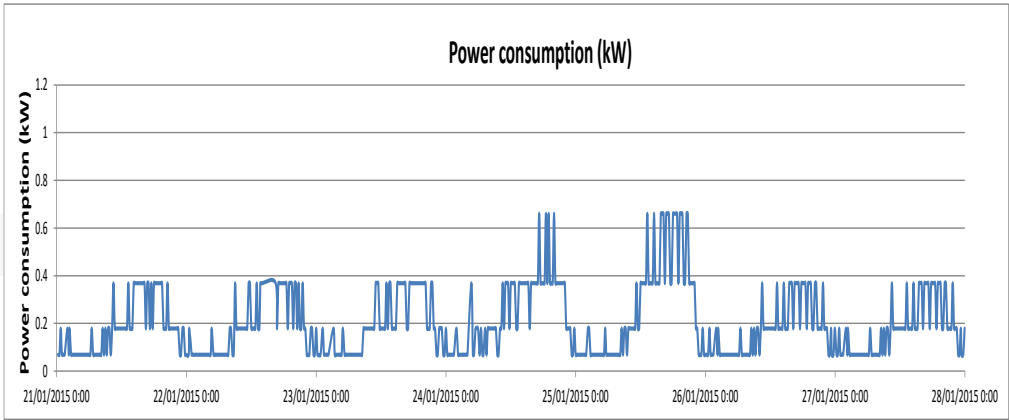




This frequency is controlled by the BEMO now

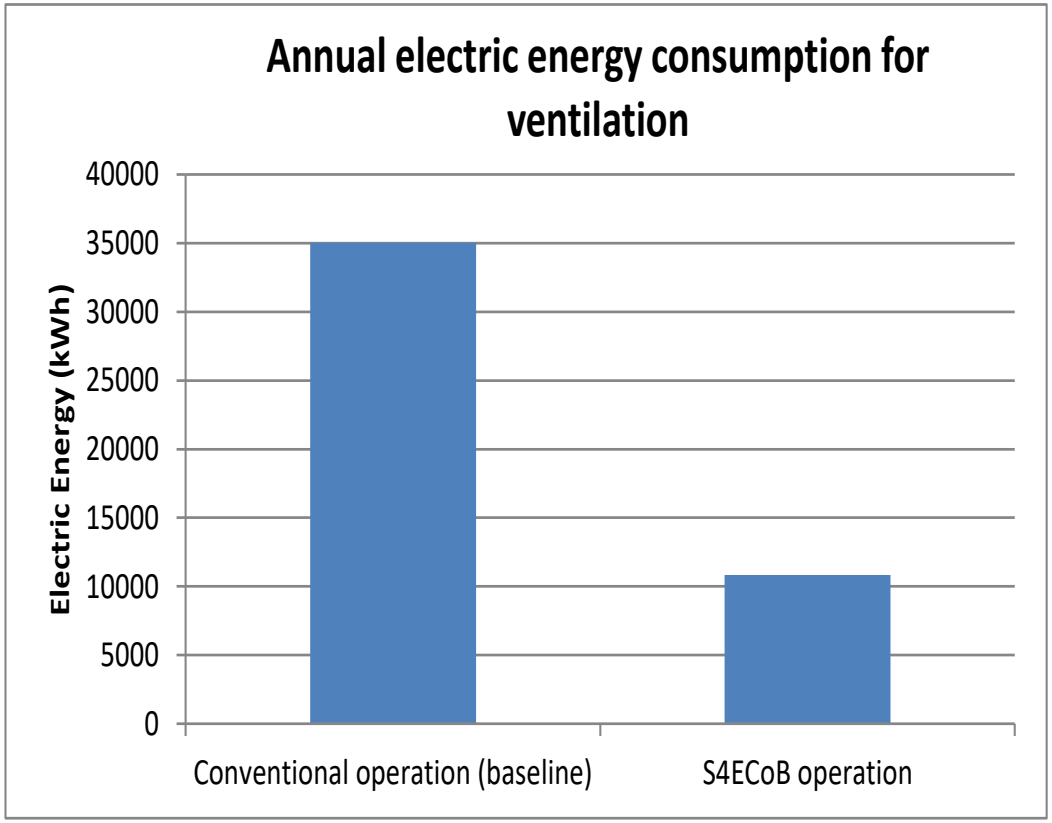






T5.3 Maremagnum – Ventilation system

- When comparing the baseline with the S4ECoB operation, for the three air handling units of Maremagnum shopping mall, the following graph is obtained.
- The percentage of energy saved when operating according to the S4ECoB strategy is 69.1%. This leads to total savings of 24 MWh.
- The total savings obtained by the S4ECoB system would represent in this case about 1.0% of the total energy consumption of the shopping mall.



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T5.4 Maremagnum – Cost Benefit Analysis

Group	Components	Capital Cost
Equipment	8-channel Microphone array incl. housing (3 pieces, 700 € each)	2,100.00 €
	Audio processing unit	522.00 €
	BEMO Server	2,250.00 €
	Installation Equipment	500.00 €
Personal Cost	Installation & Coordination	2,000.00 €
	Programming	10,000.00 €
Prestudy	Calibration	30,000.00 €
	Total	47,372,00 €

Parameter	Unit	
Period T	[a]	10
Interest rate	[%]	4
Annuity factor	[-]	0.123
Energy price inflation	[%/a]	3
Annuity factor for energy prices	[-]	1.14
Energy price - heat	[€/kWh]	N/A
Energy price - electricity	[€/kWh]	0.083

Type	Unit	Energy savings
Heat	kWh	Not applicable
Electricity		24,216
Total		24,216

Type	Unit	CO_2 savings
Heat	Kg CO_2	0
Electricity		10,655
Total		10,655

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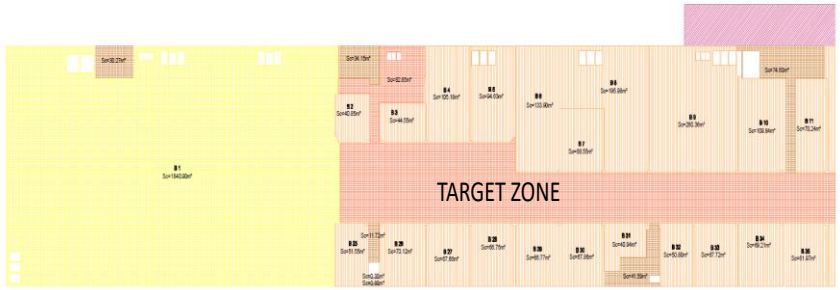
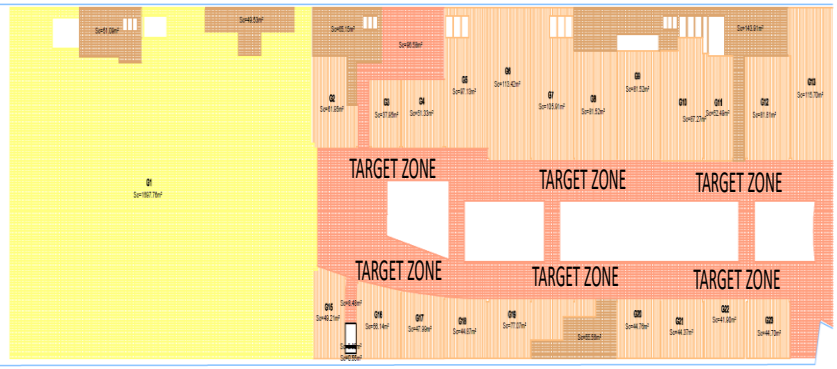
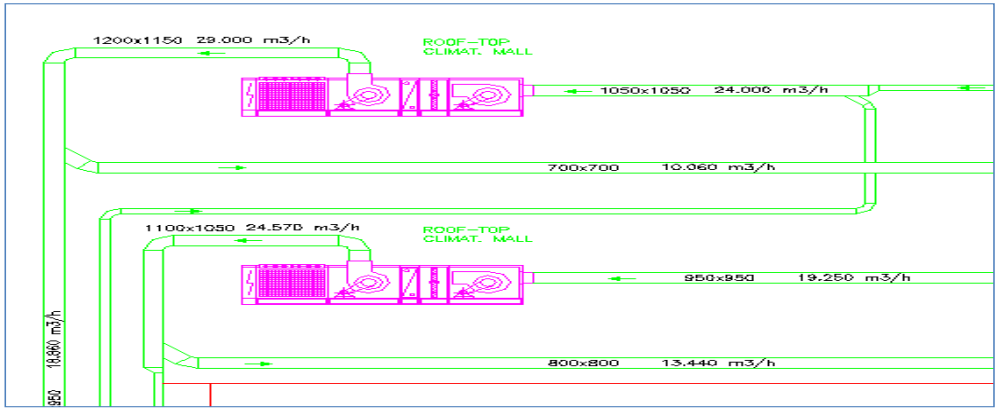
T5.3 Principe Pio – Set point control

- The mall zones are thermally conditioned by means of two rooftops autonomous units that introduce treated air inside these zones. The mall zones belong to the shopping mall owner and therefore CORIO is the company that has to guarantee the thermal comfort in these zones.
- Set point control – Optimisation => Occ0, Occ1, Occ2 =>19ºC , Occ3 & Occ4 => 21ºC







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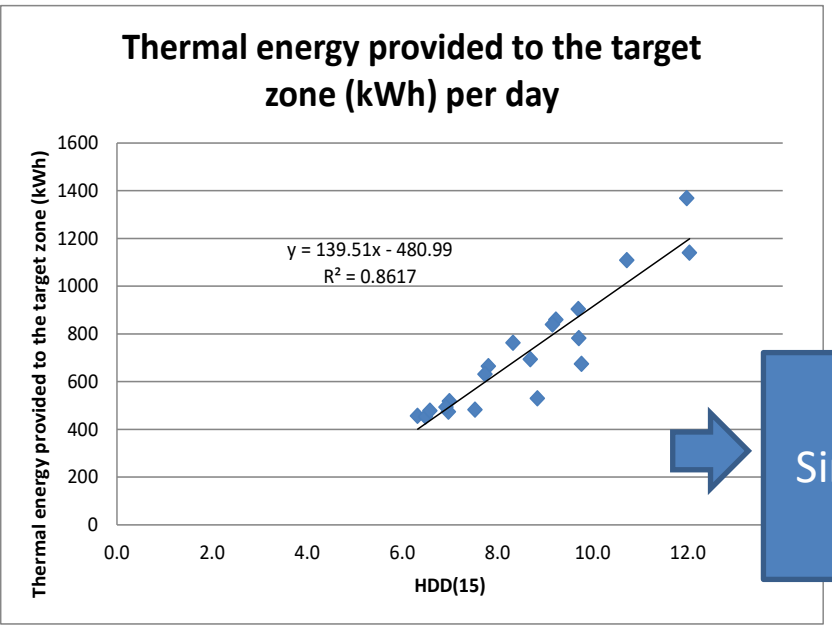
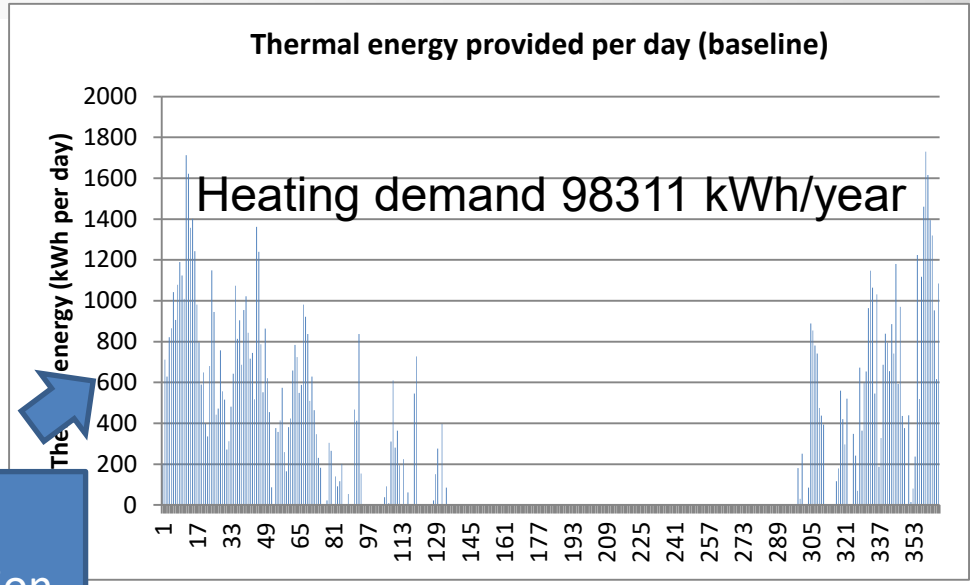
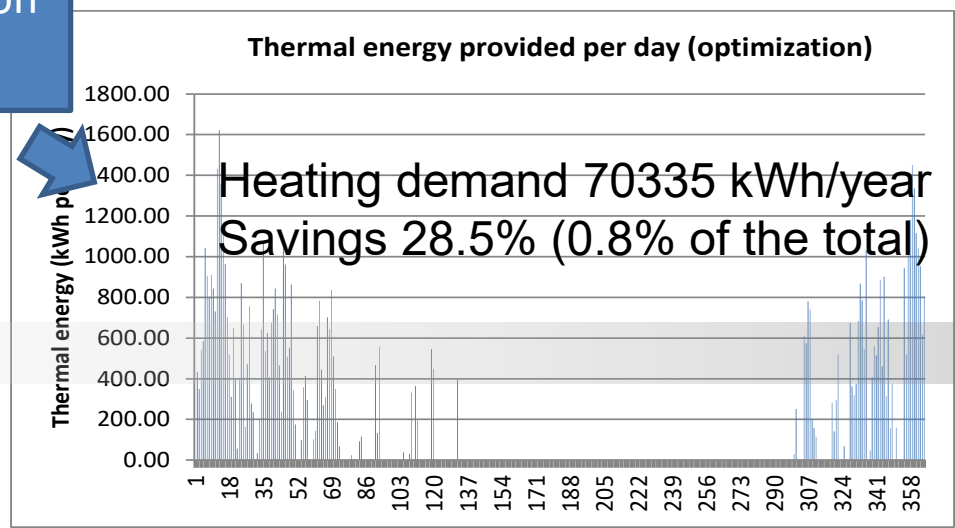
T5.3 Principe Pio – Set point control



WP6 data

Simulation





The strategy has only been applied to the target zone, in the winter period, and considering that the surrounding zones follow the same strategy. More savings could be obtained by implementing the strategy globally, and also for the summer period

T5.4 Principie Pio – Cost Benefit Analysis

Group	Components	Capital Cost
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	Total	**47,372.00 €**

Parameter	Unit	
Period T	[a]	10
Interest rate	[%]	4
Annuity factor	[-]	0.123
Energy price inflation	[%/a]	3
Annuity factor for energy prices	[-]	1.14
Energy price - electricity	[€/kWh]	N/A
Energy price - gas	[€/kWh]	0.06

Type	Unit	Energy savings
Gas	kWh	37,301
Electricity		N/A
Total		37,301

Type	Unit	CO_2 savings
Gas	Kg CO_2	10,332
Total		10,332

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T5.4 – Cost Benefit Analysis

Type	Unit	Linate	Mare Magnum	Principe Pio
Gas	kWh	639,563	-	37,301
Electricity	kWh	-	24,216	-
CO2 Savings	t CO2	161	11	10
Annuity	€/a	22,521.00 €	- 3,558.29 €	- 3,299.25 €

- For Linate Isolating energy consumption data for project area difficult due to lack of detailed metering
- Results for Maremagnum and Principie Pio not positive

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T5.5 WEB-MONITORING SYSTEM OF BEMO PERFORMANCE

Objective

- Development of a Web-Monitoring system for BEMO performance

General Comment(s)

- The present task **started at M31 instead of at M25** as for the DoW and the whole execution slid forward of about 6 months .
- No comments and remarks were available from previous reporting periods.

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T5.5 WEB-MONITORING SYSTEM OF BEMO PERFORMANCE

Achievements

- A web-based monitoring system for the energy performance of the building air conditioning systems was designed and developed in the framework of the present task.
- The monitoring system has been directly integrated into the BEMO Control and Management platform, and, thanks to the optimization unit, is capable to read and write the optimized energy data parameters from/to the enabled BMS already installed at the demonstration sites.
- A general optimization routine has been developed and integrated into the BEMO Control and Management Platform

S4ECoB is co-funded by the European Union within the 7th Framework Programme (FP7)

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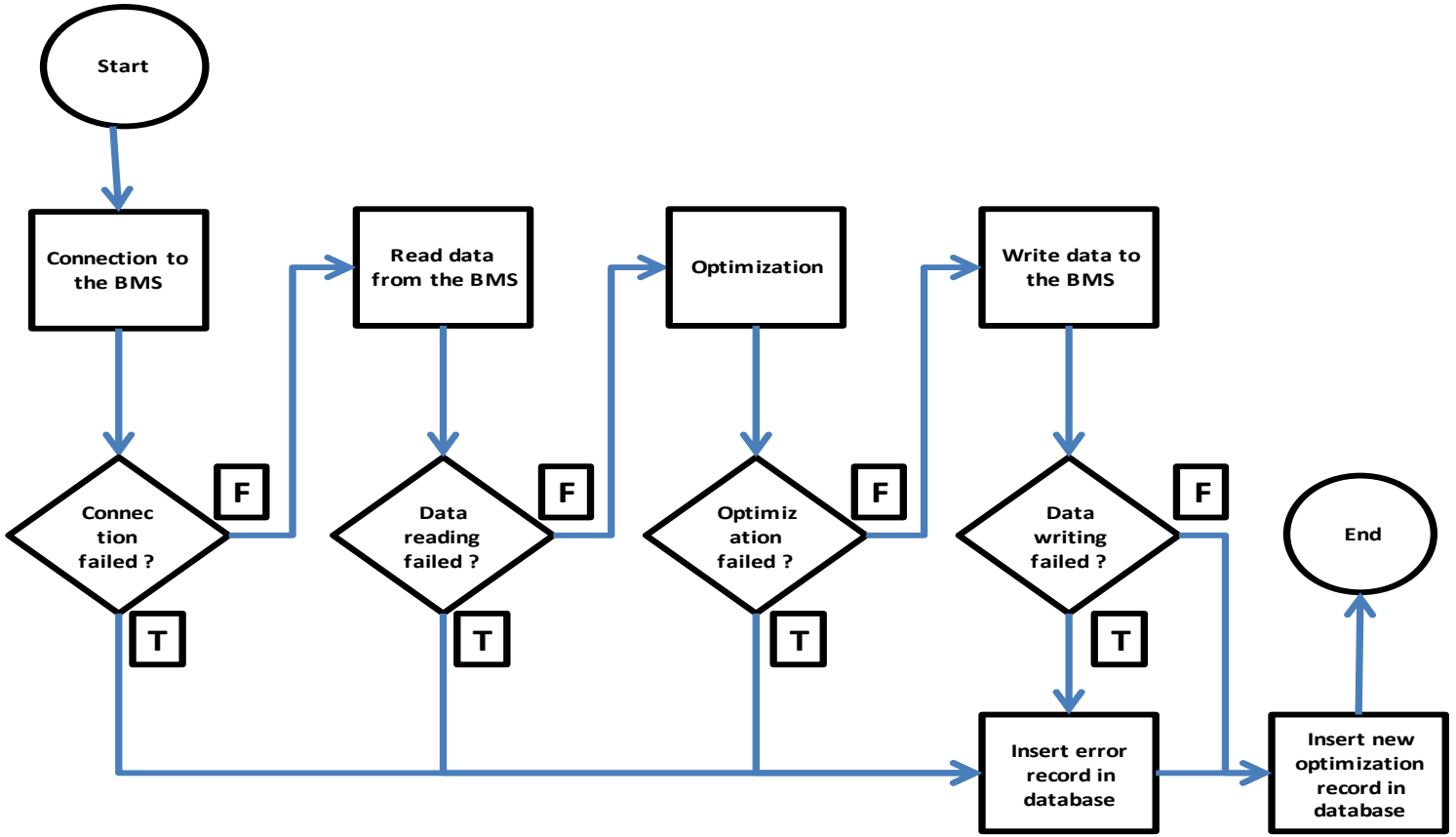

08.06.15

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T5.5 WEB-MONITORING SYSTEM OF BEMO PERFORMANCE

Achievements

- For Principe Pio the optimization unit has been implemented following the optimization logic developed, together with a controlling interface web page for manually inserting the parameters needed by the heating and cooling strategy to optimize the set point temperature of the two rooftops units.
- For Maremagnum the optimization unit has been implemented following the optimization logic developed and the optimization routine successfully managed to read and write values from/to the Schneider BMS. A controlling interface web page has been implemented in order to manually manage the optimization routine. An optimized energy monitor web page has been implemented in order to let the Optimization Manager monitor historical optimized frequency set point as well as the optimization procedure.

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T5.5 WEB-MONITORING SYSTEM OF BEMO PERFORMANCE

What was not achieved

- In Linate it was not possible to access in an automated and automatic mode the Honeywell SymmetrE BMS.
- The energy performances as well as the energy parameters of the whole building conditioning systems were not completely accessed due to limitations and constraints given by the BMS provider. An effective benchmarking or comparison of energy performance before and after the installation of the S4ECoB system was not performed even if the software platform was programmed for providing such kind of service.

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