TIMEPAC Academy

Session
HVAC Re-Commissioning – improving indoor environmental quality

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28 May 2024

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GOLEA

Lecture contents

- HVAC Re-Commissioning – Definition, considered items
  – Best practices
- Indoor environmental quality – domains, procedures, and application
- A case study: the assessment of a system condition and the Re-Co plan

Re-Commissioning

Recommissioning (RCx) is a re-optimization process for existing buildings that have already been either commissioned or retrocommissioned.

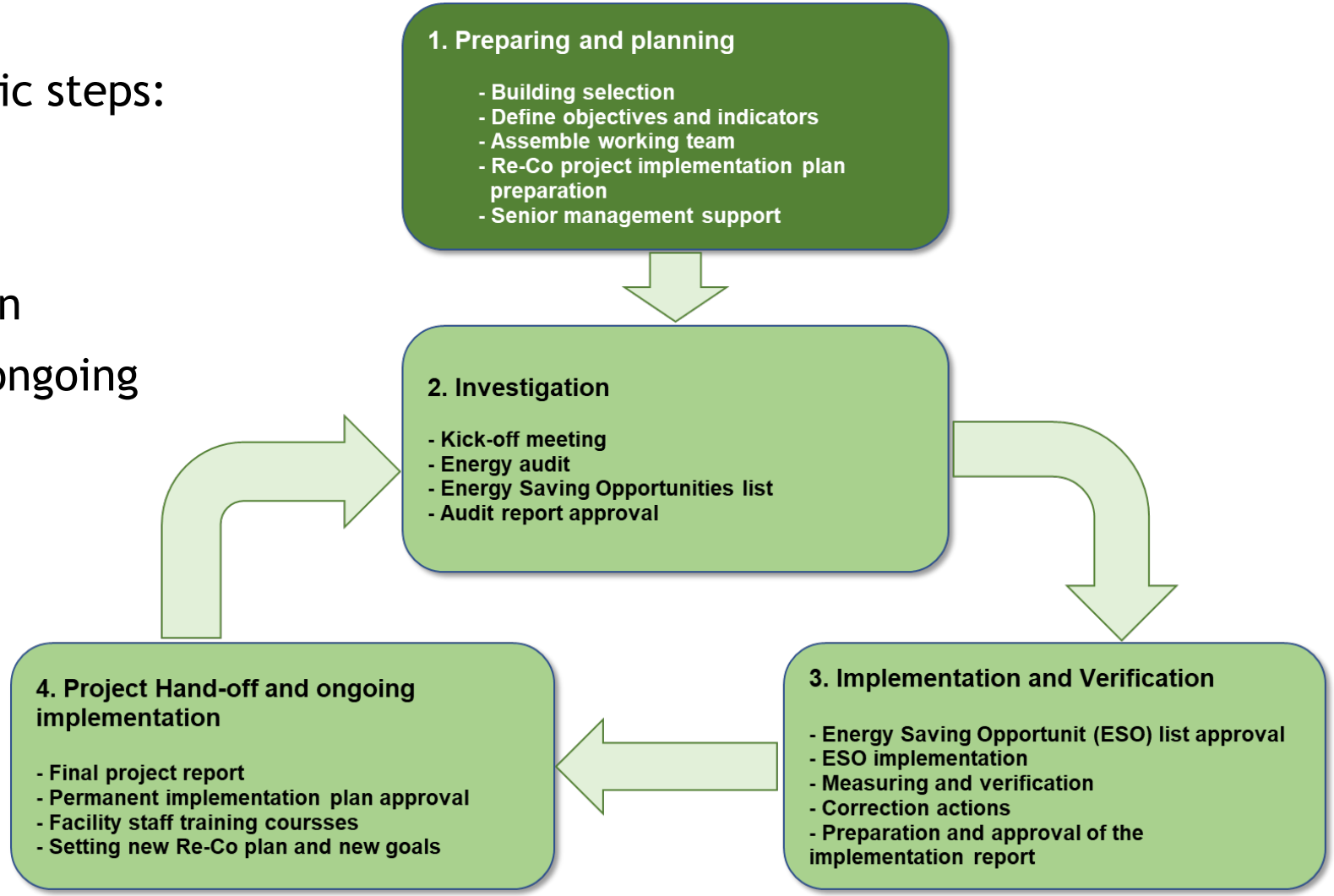
It ensures building equipment and systems are operating optimally to meet current occupant needs. It provides a rigorous investigation approach to identify problems and integration issues.

The RCx primary focus is on identifying “low cost/no cost” operational improvements given the building’s current usage to obtain comfort and energy savings. It may be done alone or in concert with a retrofit project.

Implementation of the Re-Co project in buildings

Re-Co is implemented in four basic steps:

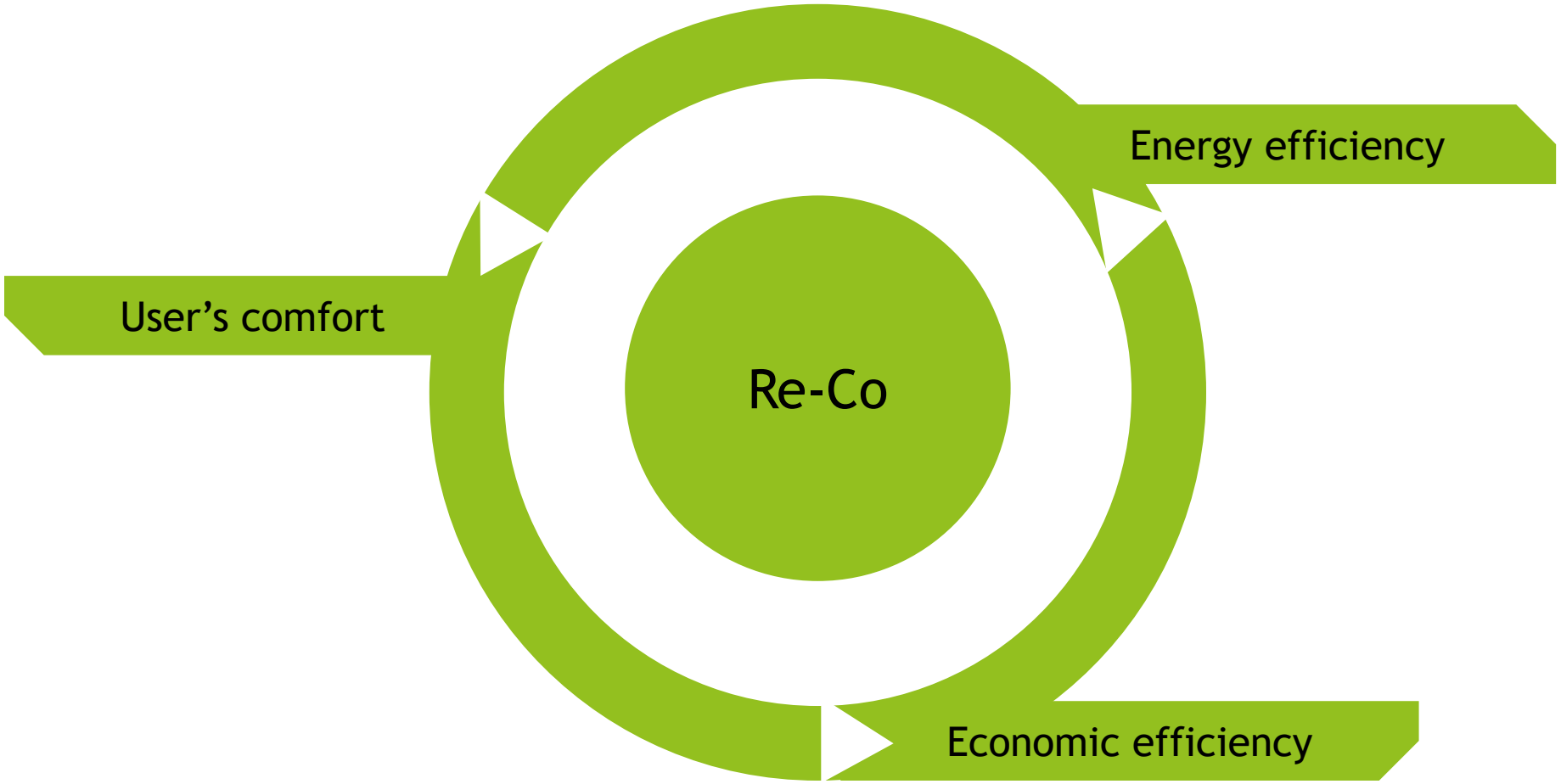
- Preparation and planning
- Investigation and analysis
- Implementation and verification
- Project hand-off and ensuring ongoing implementation



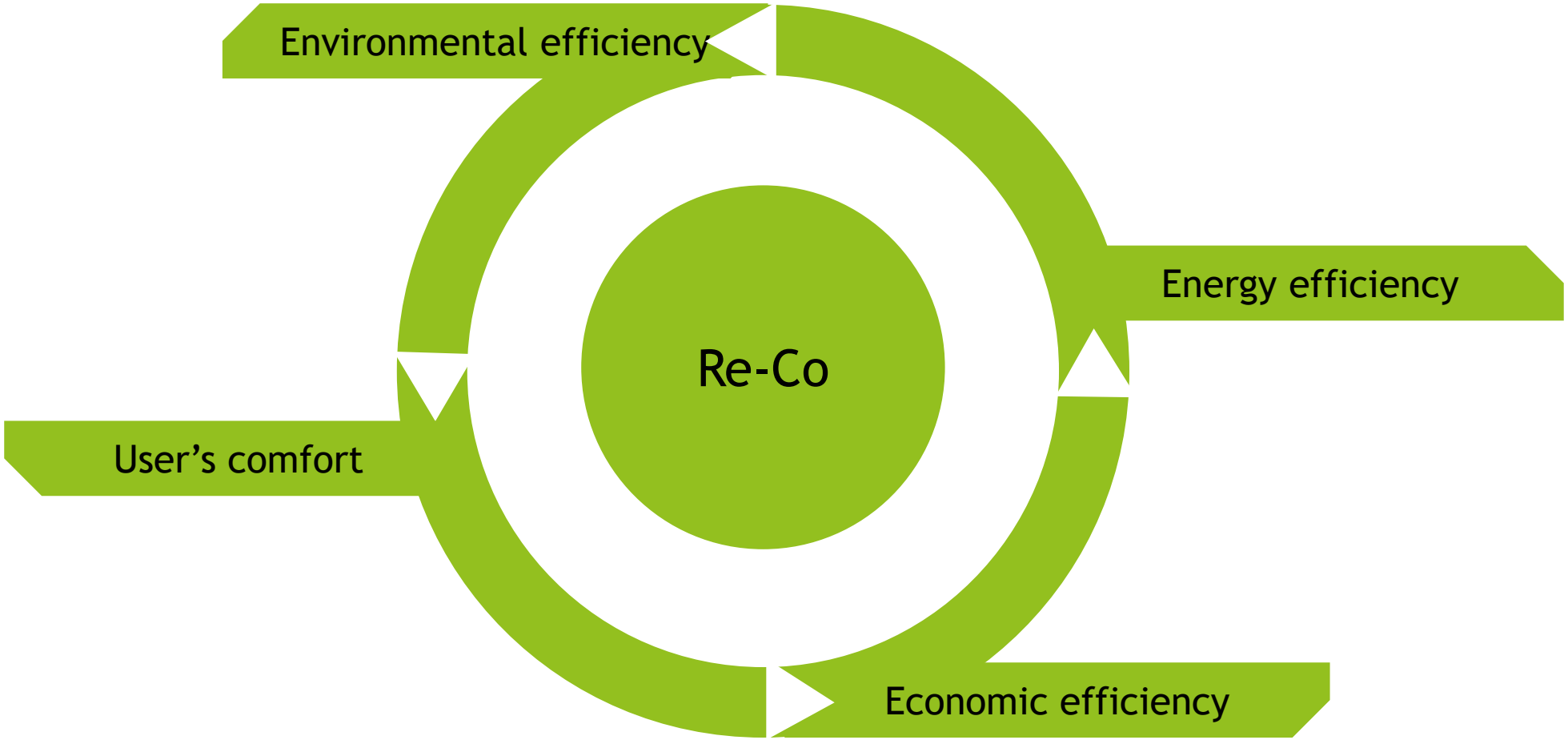
Re-Co investigation, implementation, and verification (in brief)

1. Evaluation of the problems (e.g., frequent equipment or component failure) or unsatisfied needs (e.g., users's comfort, economic, environmental)
2. Evaluation of the possible measures
3. Implementation of the measures
4. Evaluation of measures effect

Re-Co main goals



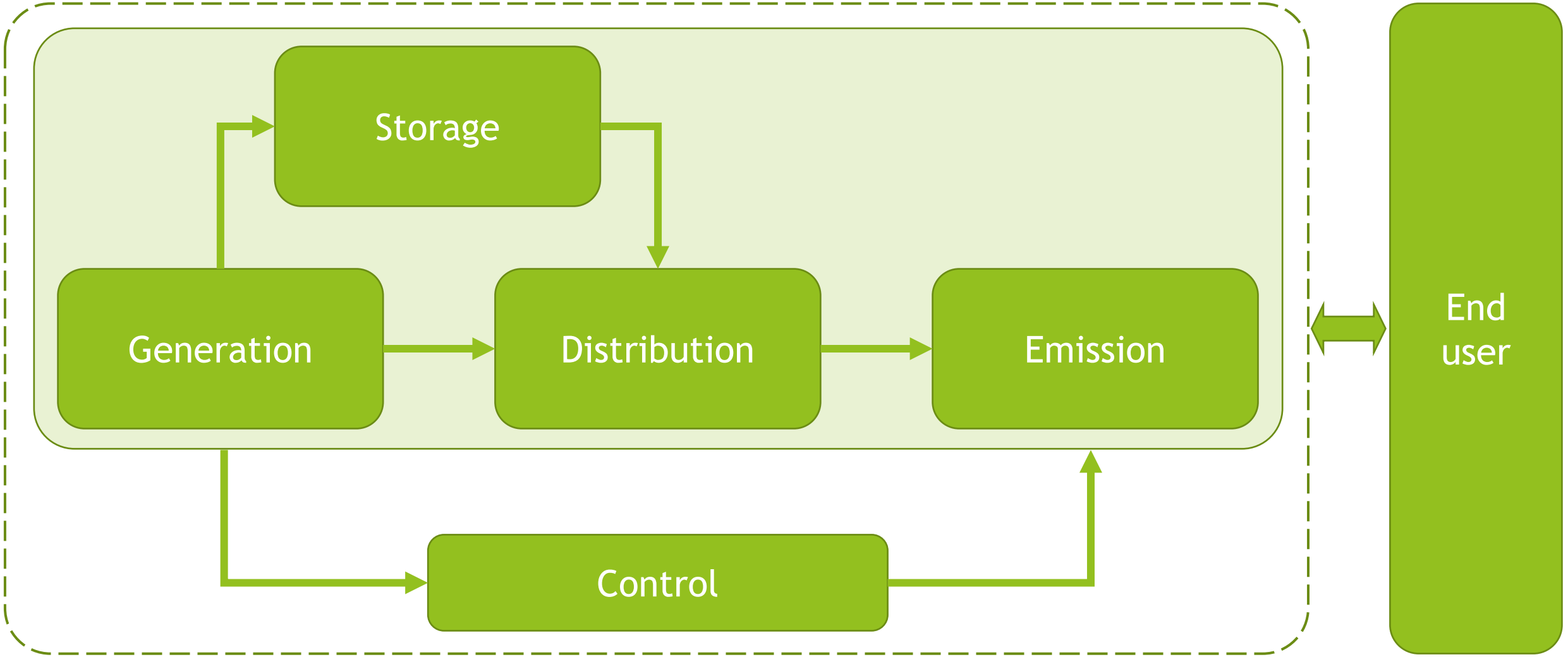
Re-Co main goals



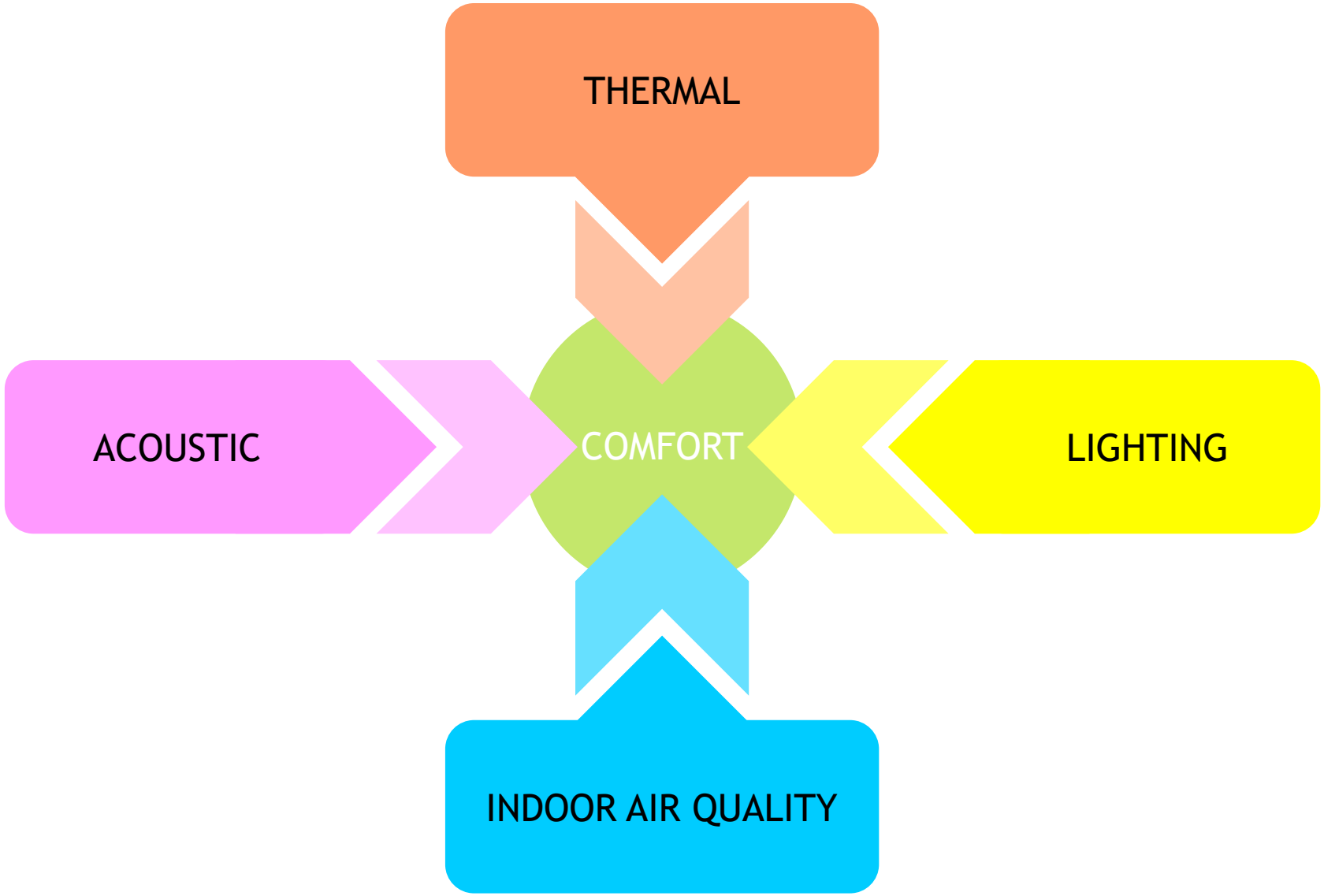
Re-Co benefits

- **Energy saving**
- Improvement of equipment performance (more durability, less maintenance)
- **Operating cost reduction**
- Increased building value
- Increase in user’s awareness
- **Indoor environmental quality (IEQ) improvement**
- Improvement of building documentation

HVAC systems



Indoor Environmental Quality (IEQ)



Indoor Environmental Quality (IEQ)

PREDICTED COMFORT VALUES

Comfort control parameters

Simulated values

Measured values

Statistically reliable parameters and limits.
May not represent the actual user's comfort

REAL USER'S COMFORT

Questionnaires filled in by the users

Only reliable if the analysed sample is big enough, or if the users do not change

Thermal Comfort – Assessment

The parameters (General thermal comfort)

Predicted Mean Vote (PMV) - it is an index that predicts the mean value of the votes of a large group of persons on the 7-point thermal sensation scale (on the right), based on the heat balance of the human body. Thermal balance is obtained when the internal heat production in the body is equal to the loss of heat to the environment. In a moderate environment, the human thermoregulatory system will automatically attempt to modify skin temperature and sweat secretion to maintain heat balance.

+ 3	Hot
+ 2	Warm
+ 1	Slightly warm
0	Neutral
– 1	Slightly cool
–2	Cool
– 3	Cold

Predicted Percentage Dissatisfied (PPD) - it is an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people who feel too cool or too warm. For this purpose, thermally dissatisfied people are those who will vote hot, warm, cool or cold on the 7-point thermal sensation scale.

EN ISO 7730:2005

Thermal Comfort – Assessment

The parameters (General thermal comfort)

$$PMV = \left[0{,}303 \cdot \exp(-0{,}036 \cdot M) + 0{,}028\right] \cdot \left\{ \begin{array}{l} (M - W) - 3{,}05 \cdot 10^{-3} \cdot \left[5\,733 - 6{,}99 \cdot (M - W) - p_a\right] - 0{,}42 \cdot \left[(M - W) - 58{,}15\right] \\ -1{,}7 \cdot 10^{-5} \cdot M \cdot (5\,867 - p_a) - 0{,}0014 \cdot M \cdot (34 - t_a) \\ -3{,}96 \cdot 10^{-8} \cdot f_{cl} \cdot \left[(t_{cl} + 273)^4 - (\overline{t_r} + 273)^4\right] - f_{cl} \cdot h_c \cdot (t_{cl} - t_a) \end{array} \right\}$$

$$h_c = \left\{ \begin{array}{ll} 2{,}38 \cdot \left|t_{cl} - t_a\right|^{0{,}25} & \text{for} \quad 2{,}38 \cdot \left|t_{cl} - t_a\right|^{0{,}25} > 12{,}1 \cdot \sqrt{v_{ar}} \\ 12{,}1 \cdot \sqrt{v_{ar}} & \text{for} \quad 2{,}38 \cdot \left|t_{cl} - t_a\right|^{0{,}25} < 12{,}1 \cdot \sqrt{v_{ar}} \end{array} \right.$$

$$f_{cl} = \left\{ \begin{array}{ll} 1{,}00 + 1{,}290\, I_{cl} & \text{for } I_{cl} \leqslant 0{,}078\ \text{m}^2 \cdot \text{K/W} \\ 1{,}05 + 0{,}645 I_{cl} & \text{for } I_{cl} > 0{,}078\ \text{m}^2 \cdot \text{K/W} \end{array} \right.$$

$$t_{cl} = 35{,}7 - 0{,}028 \cdot (M - W) - I_{cl} \cdot \left\{3{,}96 \cdot 10^{-8} \cdot f_{cl} \cdot \left[(t_{cl} + 273)^4 - (\overline{t_r} + 273)^4\right] + f_{cl} \cdot h_c \cdot (t_{cl} - t_a)\right\}$$

$$PPD = 100 - 95 \cdot \exp(-0{,}033\,53 \cdot PMV^4 - 0{,}217\,9 \cdot PMV^2)$$

where

- M is the metabolic rate, in watts per square metre (W/m^2);
- W is the effective mechanical power, in watts per square metre (W/m^2);
- I_{cl} is the clothing insulation, in square metres kelvin per watt ($m^2 \cdot K/W$);
- f_{cl} is the clothing surface area factor;
- t_a is the air temperature, in degrees Celsius (°C);
- $\overline{t_r}$ is the mean radiant temperature, in degrees Celsius (°C);
- v_{ar} is the relative air velocity, in metres per second (m/s);
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EN ISO 7730:2005

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EN ISO 7730:2005

Thermal Comfort – Assessment

The parameters (Local thermal comfort)

Draught $$DR = (34 - t_{a,l})(\bar{v}_{a,l} - 0{,}05)^{0{,}62}(0{,}37 \cdot \bar{v}_{a,l} \cdot Tu + 3{,}14)$$

Vertical air temperature difference $$PD = \frac{100}{1 + \exp(5{,}76 - 0{,}856 \cdot \Delta t_{a,v})}$$

where

$t_{a,l}$ is the local air temperature, in degrees Celsius, 20 °C to 26 °C;

$\bar{v}_{a,l}$ is the local mean air velocity, in metres per second, $<$ 0,5 m/s;

Tu is the local turbulence intensity, in percent, 10 % to 60 % (if unknown, 40 % may be used).

PD percentage dissatisfied, %

$\Delta t_{a,v}$ vertical air temperature difference between head and feet, °C

EN ISO 7730:2005

Thermal Comfort – Assessment

The parameters (Local thermal comfort)

Warm and cool floors

$$PD = 100 - 94 \cdot \exp(-1{,}387 + 0{,}118 \cdot t_f - 0{,}002\,5 \cdot t_f^2)$$

Radiant asymmetry

$$PD = \frac{100}{1 + \exp(a - b \cdot \Delta t_{pr})} - c$$

	a	b	c
Warm ceiling	2,84	0,174	3,5
Warm wall	3,72	0,052	5,5
Cool ceiling	9,93	0,50	0
Cool wall	6,61	0,345	0

PD percentage dissatisfied, %

t_f floor temperature, °C

Δt_{pr} radiant temperature asymmetry, °C

EN ISO 7730:2005

Acoustic Comfort – Assessment

The parameters

For the building service systems: A-weighted equivalent sound pressure level, normalised with respect to reverberation time $L_{A,eq,nT}$

$$L_p = L_w + 10\log\left[\frac{Q}{4\pi r^2} + \frac{4}{R}\right]$$

where

- L_p is the sound pressure level, dB (re 20 μPa);
- L_W is the sound power level, dB (re 10^{-12} W);
- Q is the directivity of sound source, dimensionless;
- r is the distance from source, m;
- R is the room constant, dimensionless.

$$R = \frac{A}{1 - \frac{A}{S_t}} \text{ and } A = 0.161\frac{V}{T_0}$$

where

- A is the total equivalent acoustic absorption, m^2;
- S_t is the total inner surface of the room, m^2;
- V is the volume, m^3;
- T_0 is the reverberation time, s.

EN 16798-1:2019
EN ISO 16032:2024

Lighting Comfort – Assessment
The parameters

Mantained illuminance (E_m) - value below which the average illuminance over a specified surface is not permitted to fall
Illuminance (E) - density of incident luminous flux with respect to area at a point on a real or imaginary surface

$$E_v = \frac{d\Phi_v}{dA}$$

where Φ_v is luminous flux and A is the area on which the luminous flux is incident

Lighting Comfort – Assessment
The parameters

Glare = "condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution or range of luminance, or by extreme contrasts

Glare from daylight – Daylight Glare Probability

$$DGP = 5,87 \times 10^{-5} \times E_v + 9,18 \times 10^{-2} \times \log\left(1 + \sum_i \frac{L_{s,i}^2 \times \omega_{s,i}}{E_v^{1,87} \times P_i^2}\right) + 0,16$$

Where
E_v is the vertical illuminance at eye level [lx],
L_s is the luminance of glare source [cd/m^2],
P is the position index [-],
ω_s is the solid angle subtended by the glare source [sr].
i is the number of glare sources

EN 14501:2021

Lighting Comfort – Assessment
The parameters

Glare from electric light - Unified Glare Rating

$$R_{UG} = 8 \log_{10}\left(\frac{0,25}{L_B}\sum\frac{L^2\,\omega}{p^2}\right)$$

where

R_{UG} is the value of the Unified Glare Rating (UGR),

L_B is the background luminance in cd·m^{-2}, calculated as $E_{ind} \cdot \pi^{-1}$, in which E_{ind} is the vertical indirect illuminance at the observer's eye,

L is the luminance in cd·m^{-2} of the luminous parts of each luminaire in the direction of the observer's eye,

ω is the solid angle in steradian of the luminous parts of each luminaire at the observer's eye,

p is the Guth position index for each individual luminaire which relates to its displacement from the line of sight.

EN 12464-1:2021

IAQ Comfort – Assessment
The parameters

Ventilation flow rates based on perceived air quality:

$$q_{tot} = n \cdot q_p + A_R \cdot q_B$$

where

q_{tot} = total ventilation rate for the breathing zone, l/s

n = design value for the number of the persons in the room,

q_p = ventilation rate for occupancy per person, l/(s person)

A_R = floor area, m^2

q_B = ventilation rate for emissions from building, $l/(s \cdot m^2)$

EN 16798-1:2019

IAQ Comfort – Assessment
The parameters

Ventilation flow rates using limit values for substance concentration:

$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} \cdot \frac{1}{\varepsilon_v}$$

where

Q_h is the ventilation rate required for dilution, in m^3 per second;

G_h is the generation rate of the substance, in micrograms per second;

$C_{h,i}$ is the guideline value of the substance, in micrograms per m^3;

$C_{h,o}$ is the concentration of the substance of the supply air, in micrograms per m^3;

ε_v is the ventilation effectiveness.

EN 16798-1:2019

Application

An exercise presenting a Re-Co on an office building is proposed following these steps:

- Presentation of the case study
- Analysis of the current building main deficiencies and possible improvements
- Analysis of the results (using a simulative approach) from an economic and comfort point of view

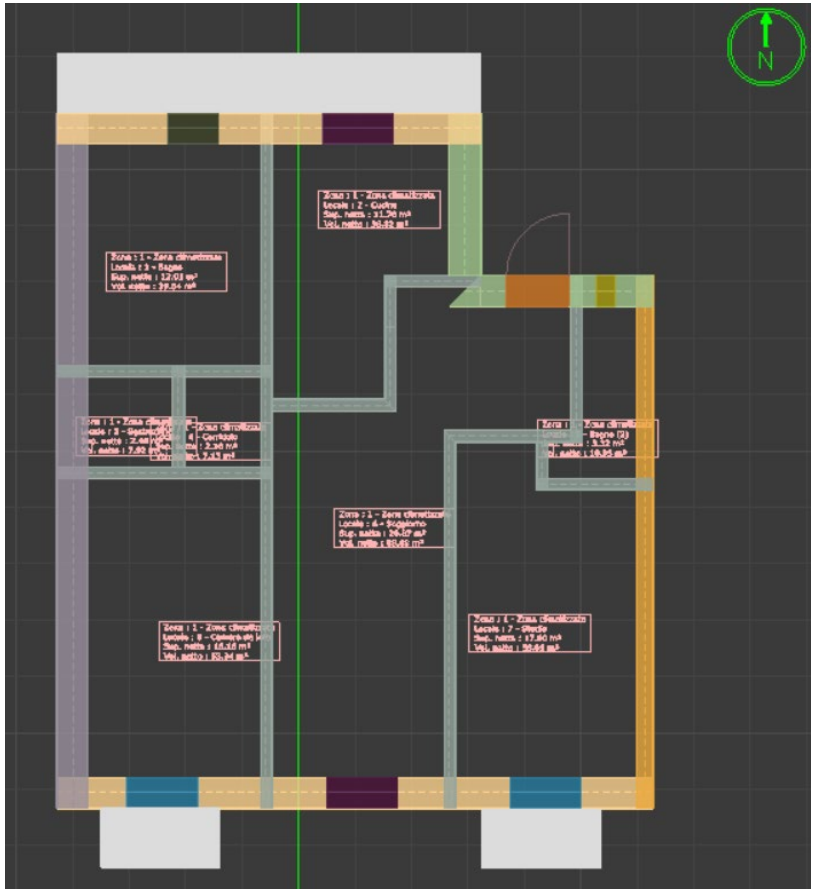
The case study

- The analysed «building» is composed of a group of rooms originally intended as residential. After a refurbishment the spaces were reused for offices;
- The space has two sides adjacent to the external environment, north and south-faced;
- The building presents a heating system with a zone thermostat and mechanical ventilation system. The HVAC systems were pre-existent. The only adjustment was performed on the thermostat schedule

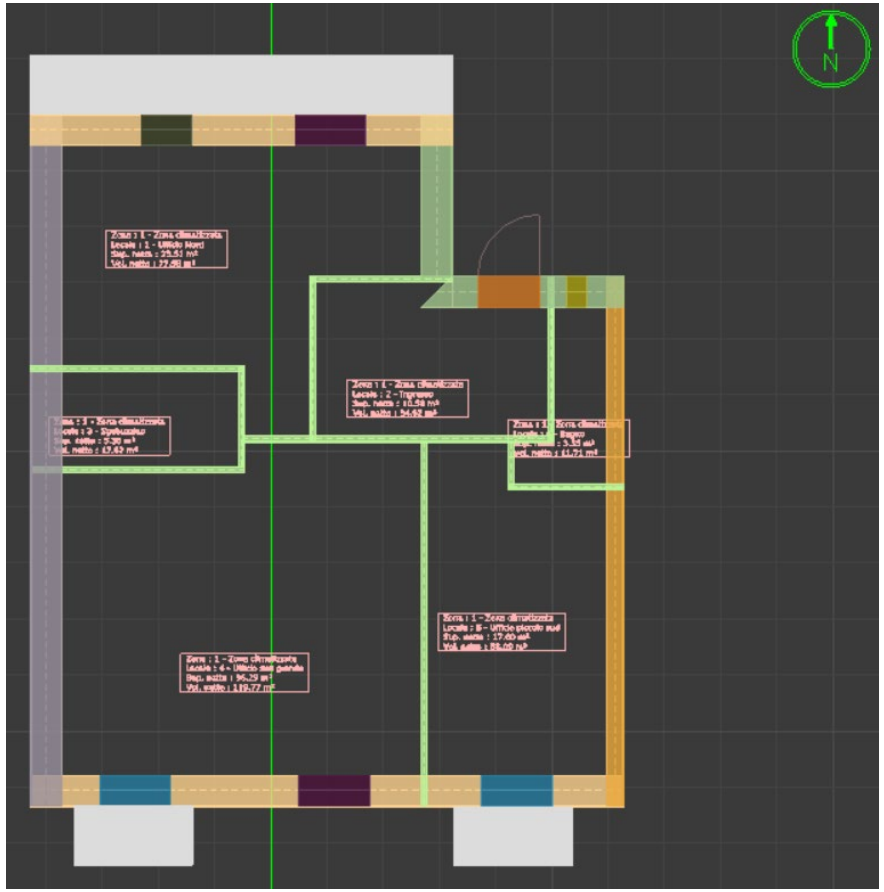
The case study

The plans

Residential



Office



The case study
The systems

The zone is provided with four building services: heating, lighting, domestic hot water (DHW), and ventilation.

Heating	
Generation	A gas condensing boiler used only by the zone is installed in one of the balconies
Storage	-
Distribution	Well-insulated pipes with water manifolds
Emission	Radiators on the external walls
Control	On/off zone control

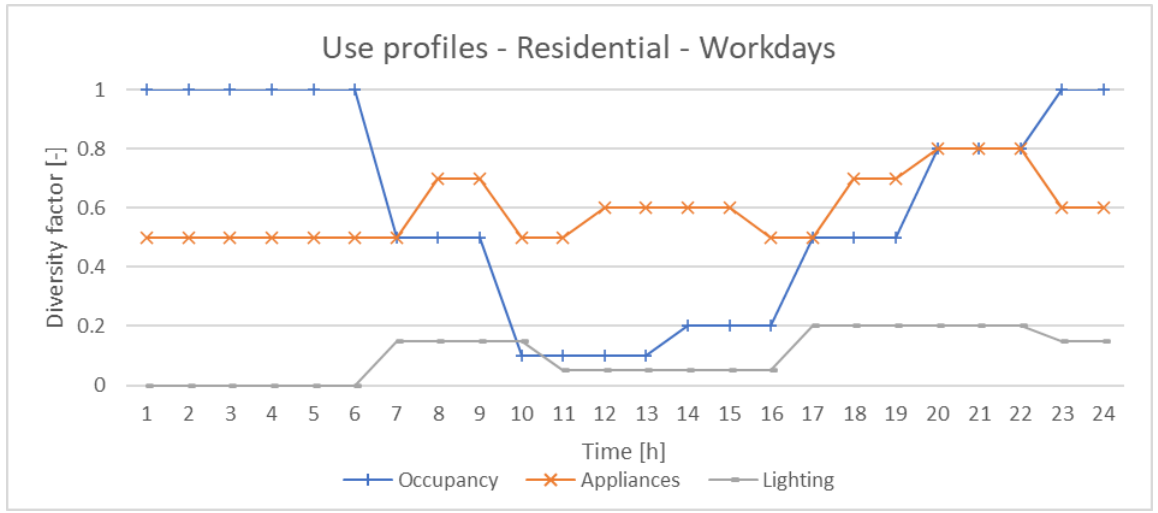
The case study
The systems

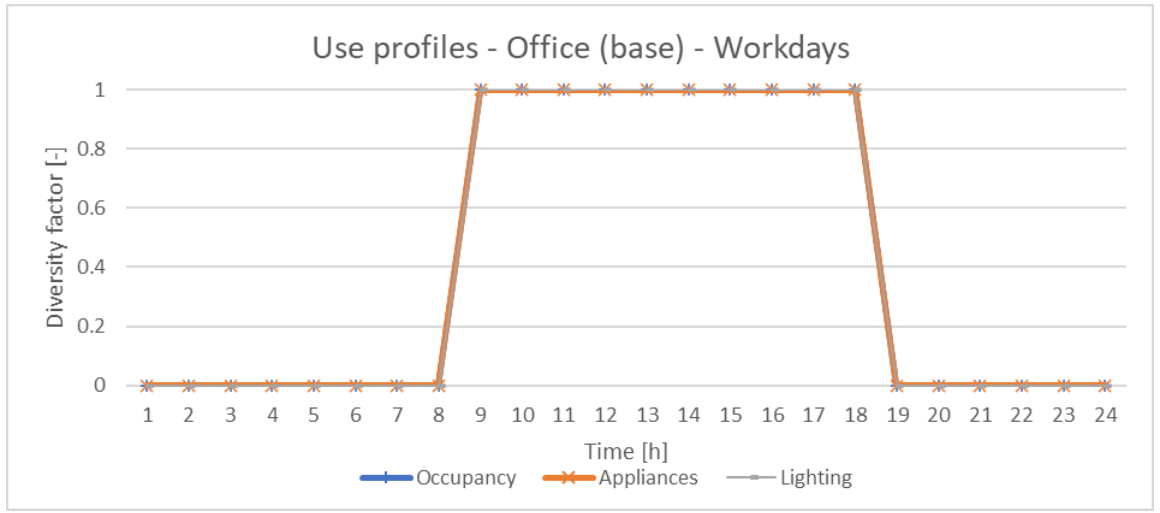
The zone is provided with four building services: heating, lighting, domestic hot water (DHW), and ventilation.

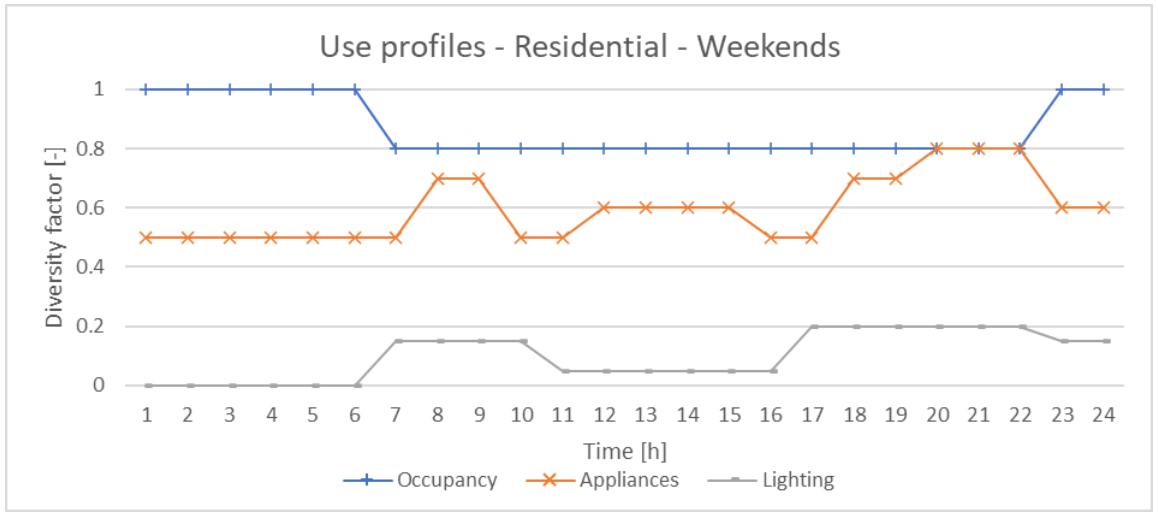
- Lighting – LED lamps in all the rooms
- DHW – Same generation as the heating service
- Ventilation – Balanced mechanical ventilation in all the rooms

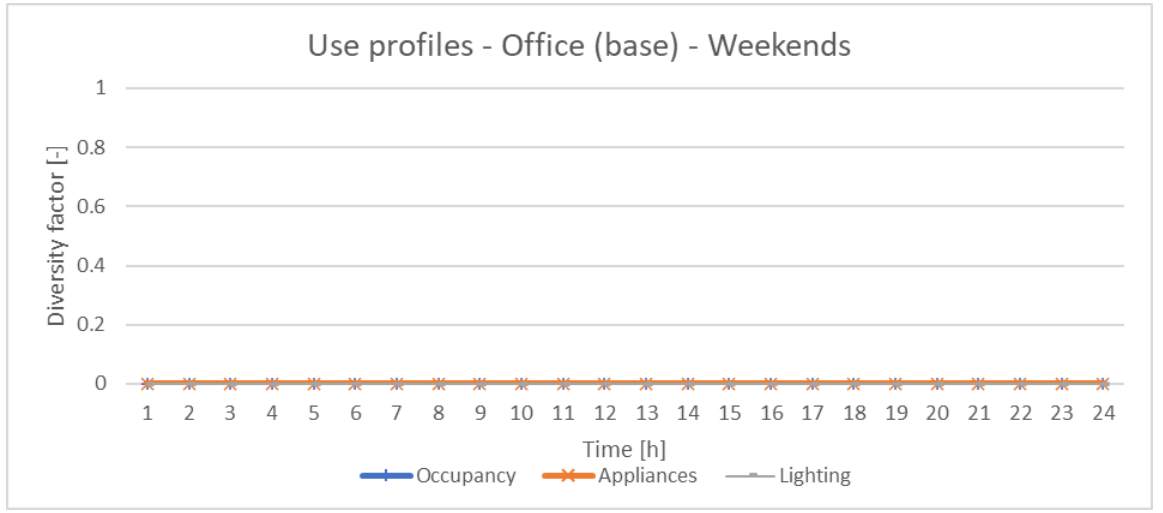
The case study

User profiles



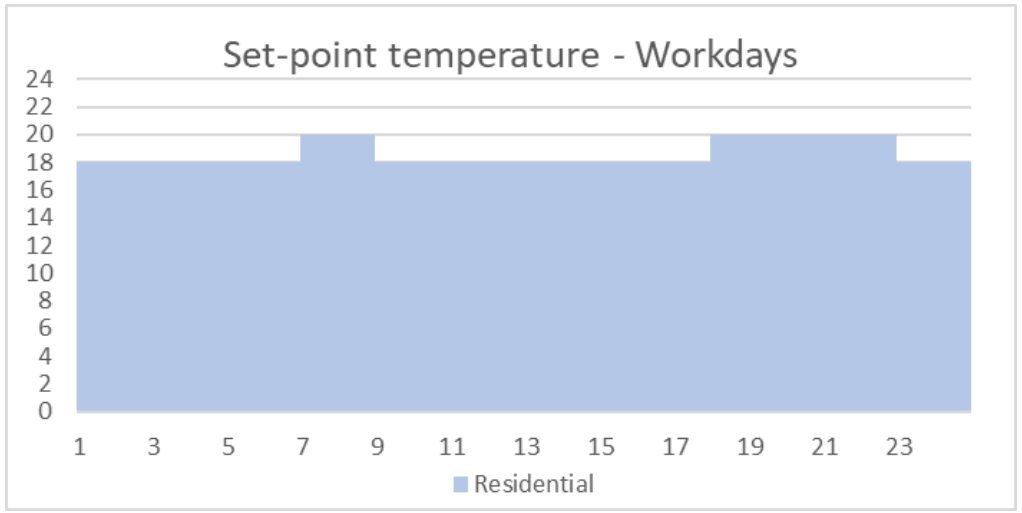


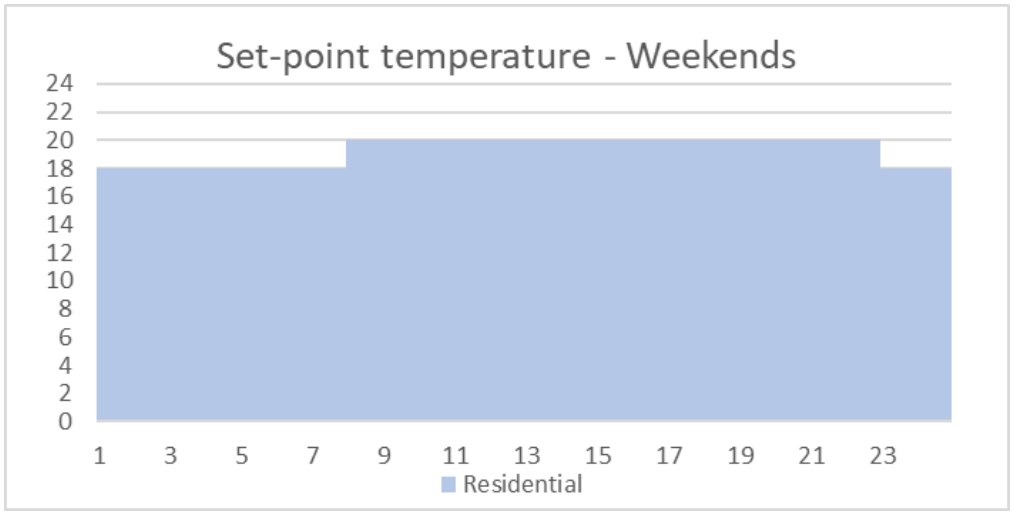


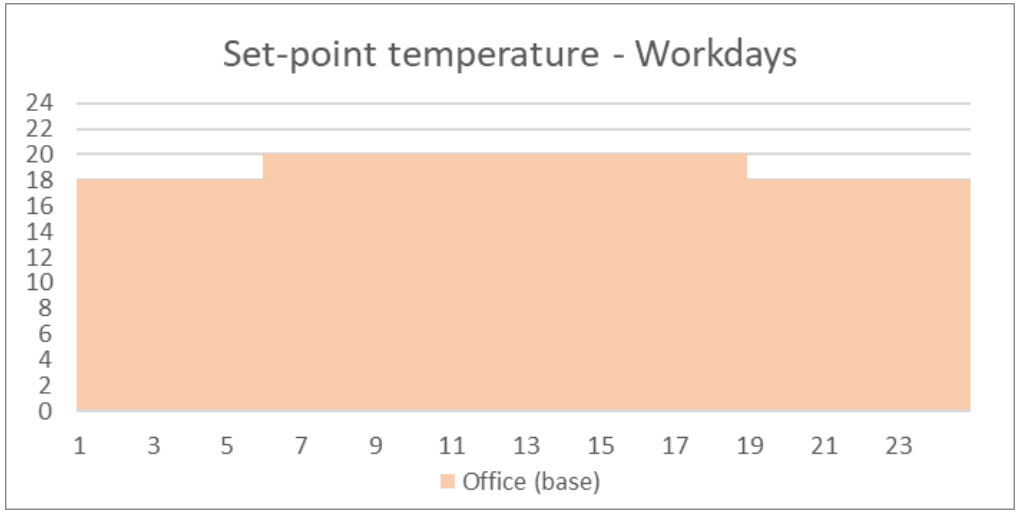


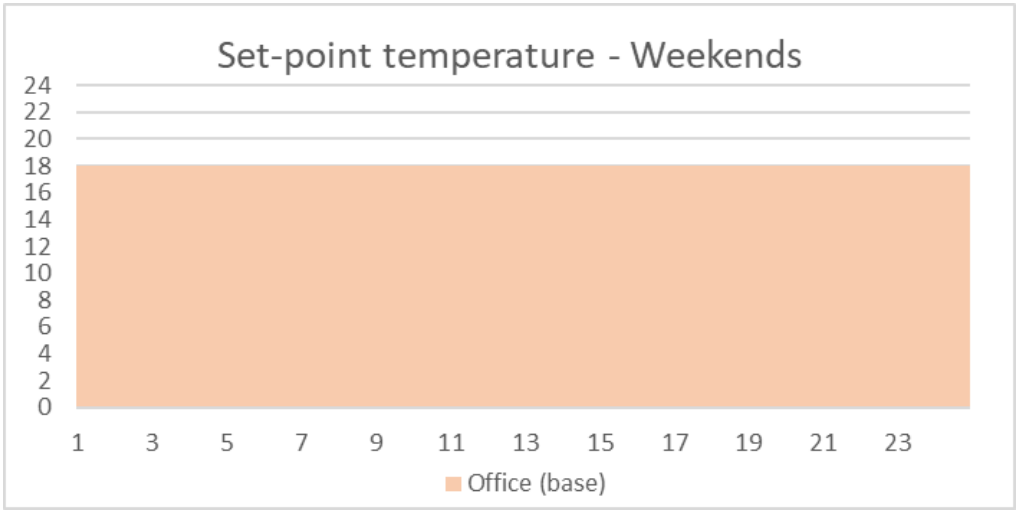
The case study

Temperature set-points









Why is a RCx needed?

Why is a RCx needed?

- The building had an occupancy modification
- The current users are facing some thermal comfort problems. In particular, in some cases, the heating system is running but, in the offices south-oriented the temperature is over the comfort levels while in the north office the temperature is below the comfort levels

The investigation - measurements

Three measurement campaigns were carried out

- The internal air, mean radiant, and operative temperatures in the offices
- The actual occupancy of the offices
- An analysis of the ventilation system schedule

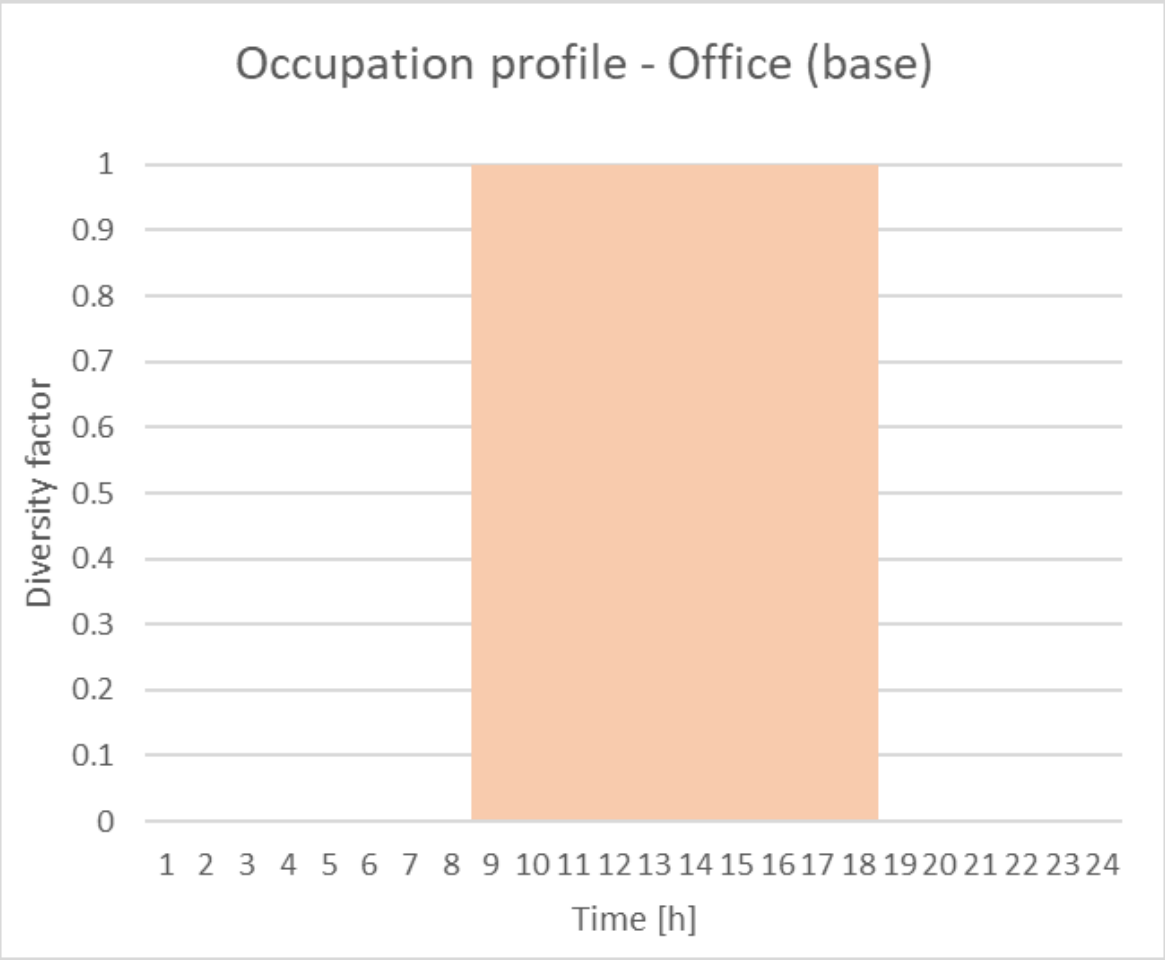
The investigation - inspection

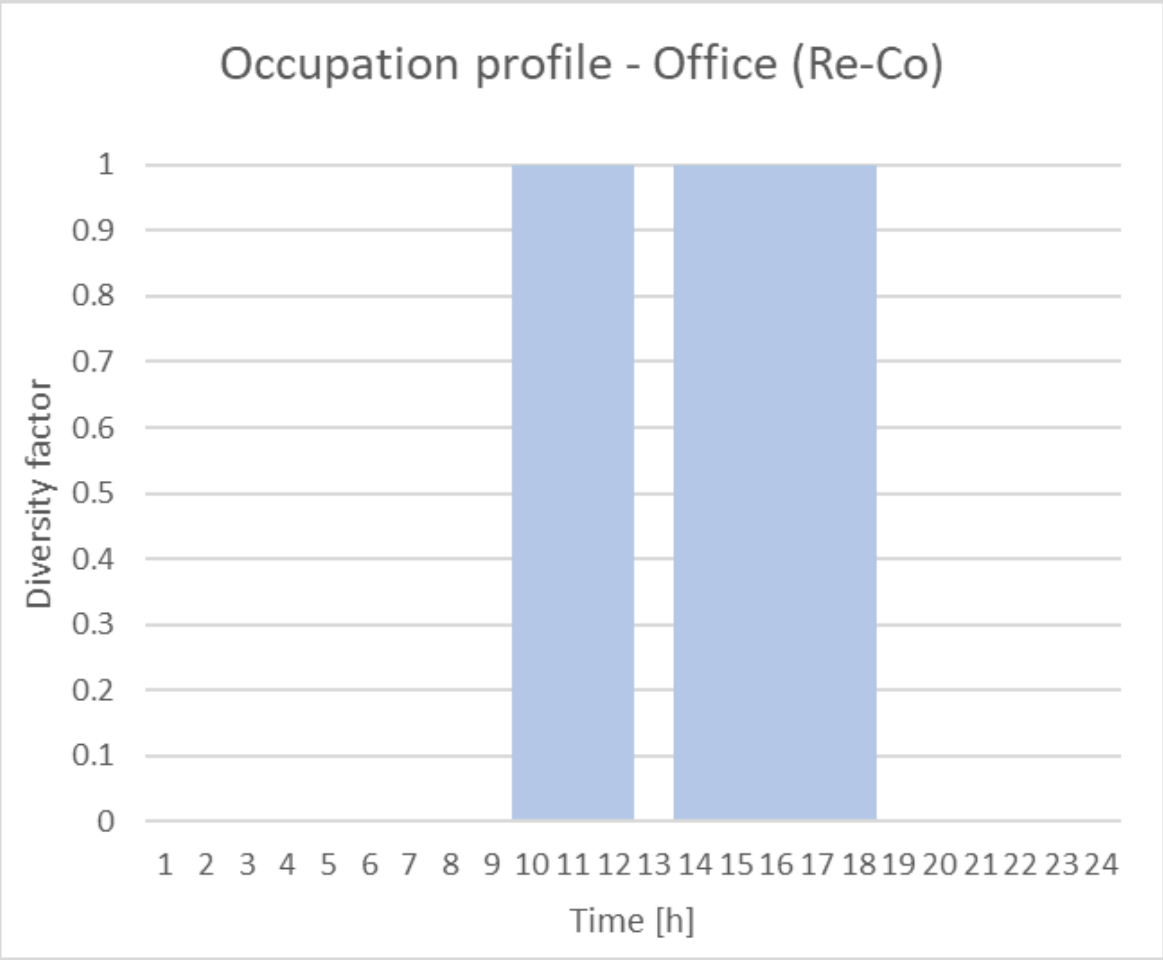
The existing building systems were inspected to find any possible malfunctioning in the systems. In particular:

- An inspection of the boiler, to analyse the actual performance and pollutants emission compared to the standard data
- An inspection of the existing LED lamps
- An inspection of the ventilation ducts.

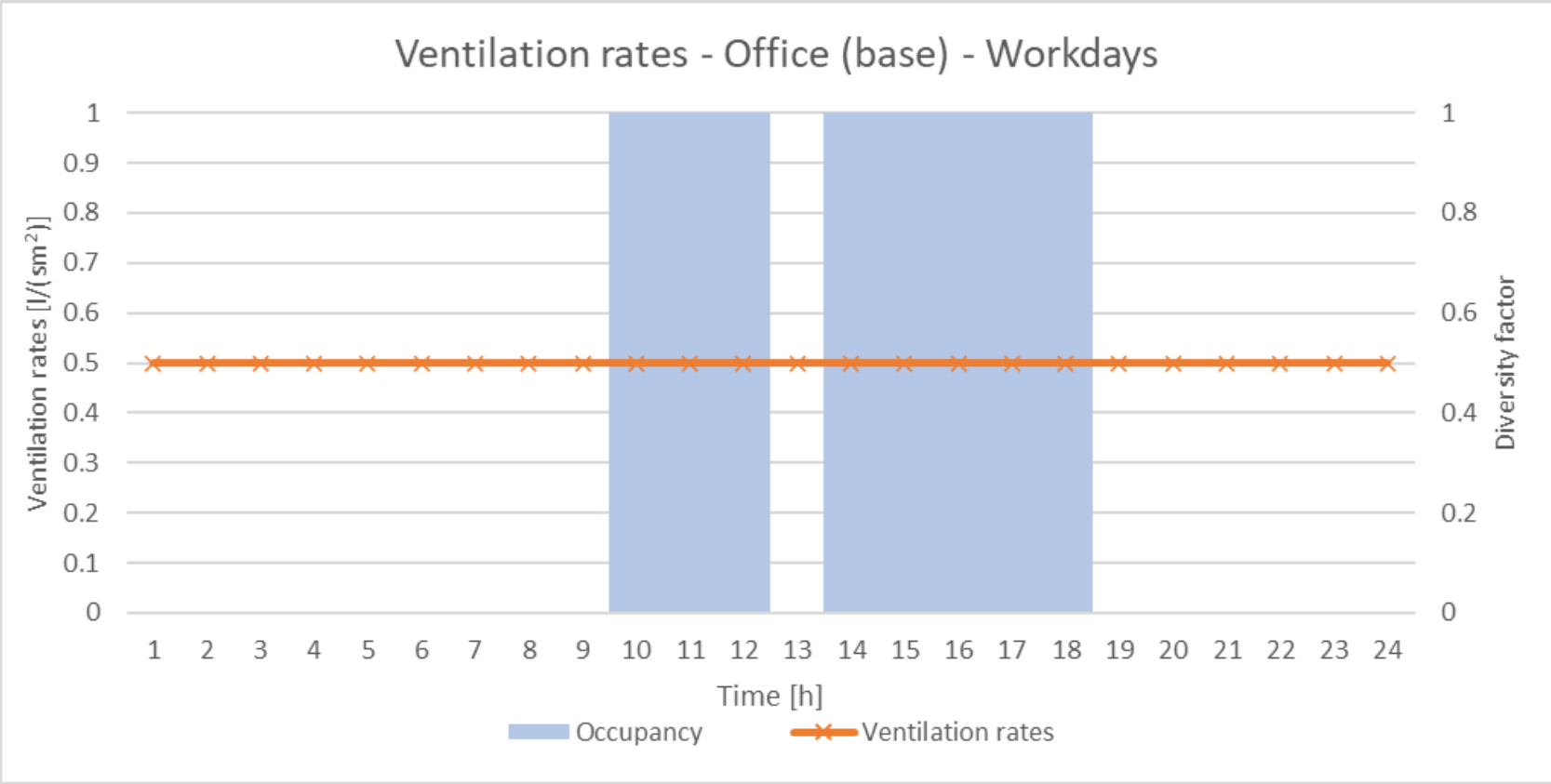
The results of the investigation

Occupancy time





The results of the investigation
Ventilation rates

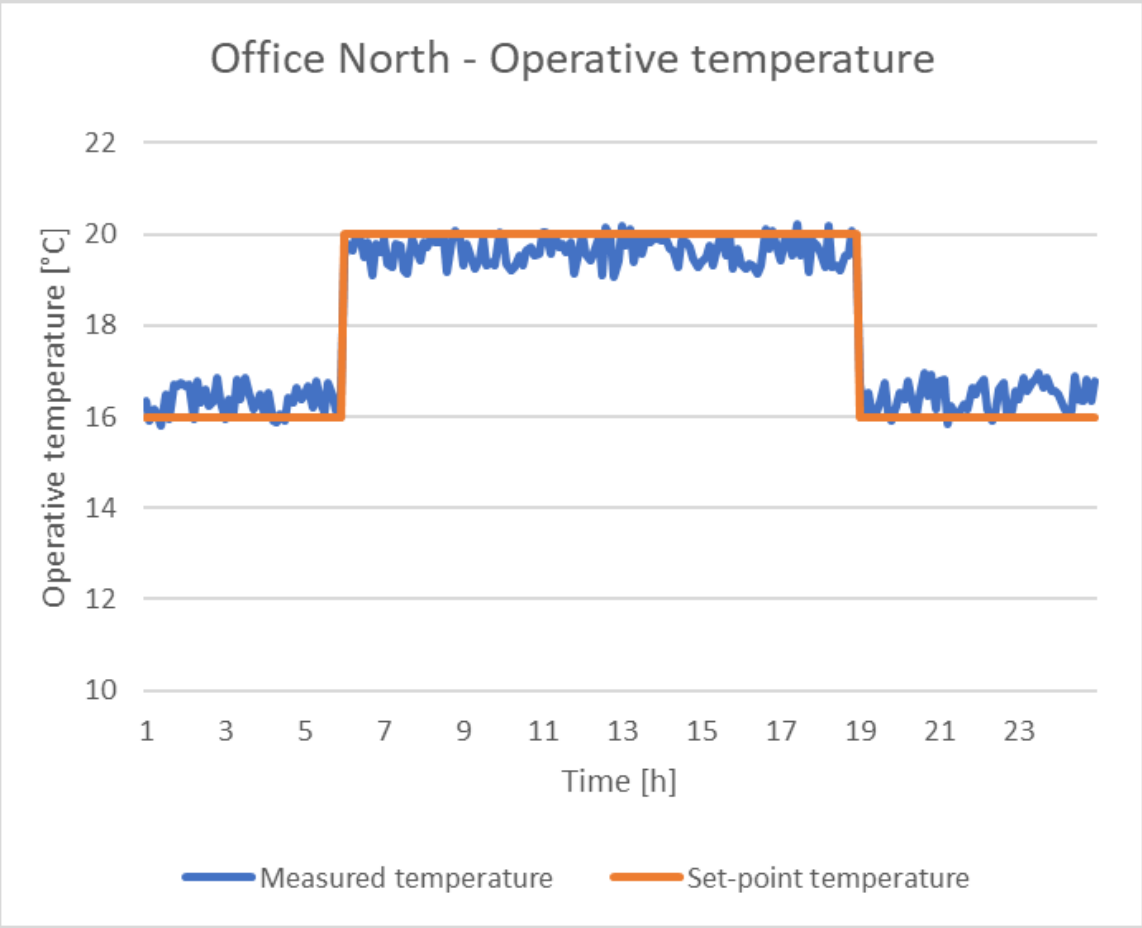


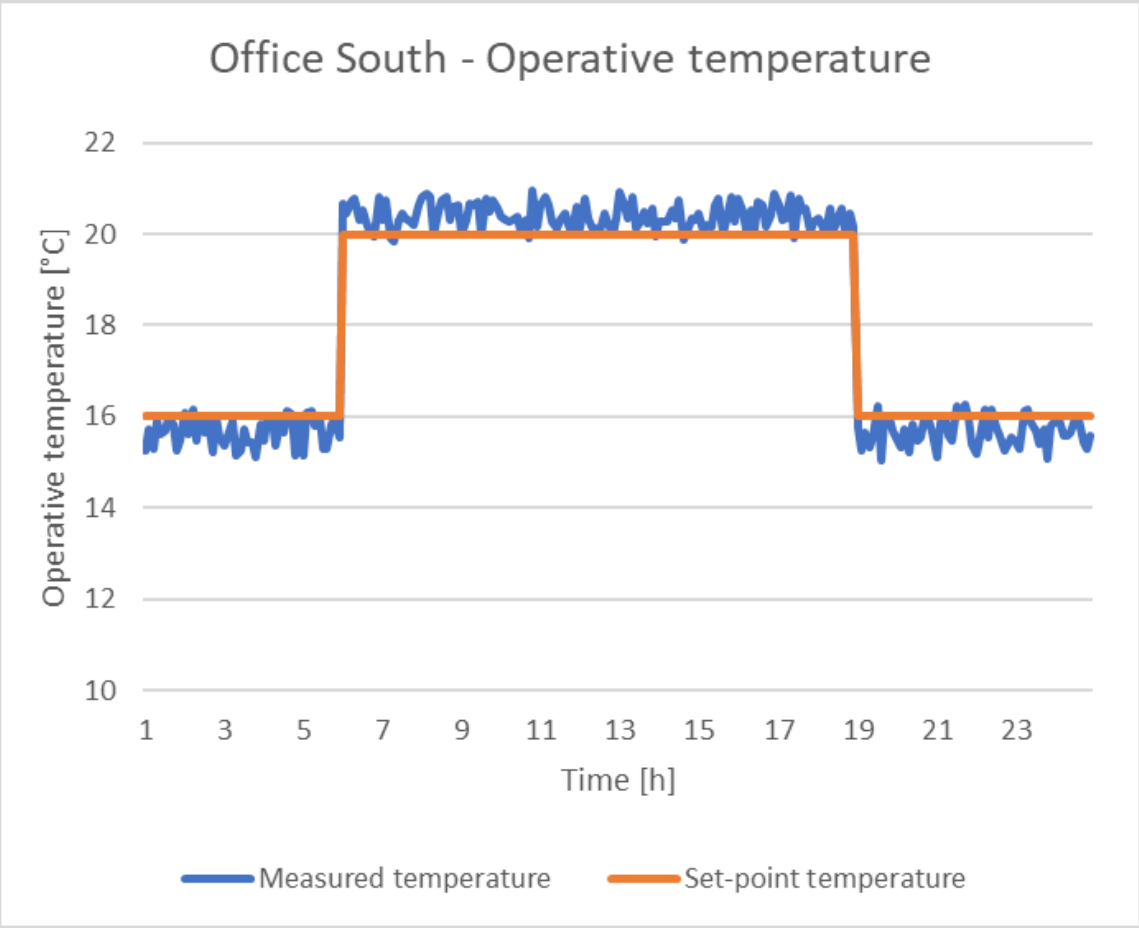
Flow rate	Value [l/sm²]
Minimum (Residential – EN 16798-1)	0,5
Minimum (Office – EN 16798-1)	1,0
IAQ (Office – EN 16798-1*)	1,4

*Considering a level 2 comfort category and low building polluting level

The results of the investigation

Offices temperature





The results of the investigation

The inspection

The results of the inspections carried out highlighted no problems with the current systems.

No deficiencies were found.

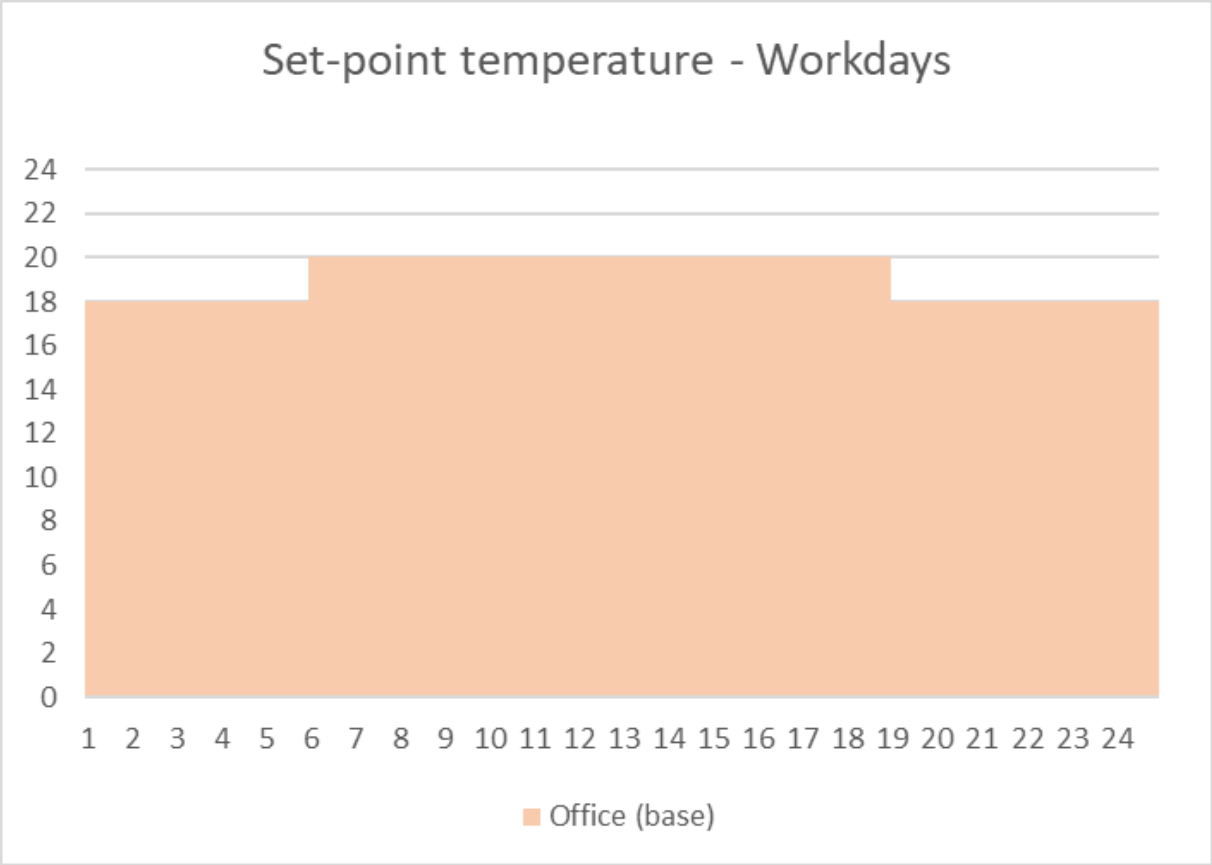
The systems performance was in line with the expectations.

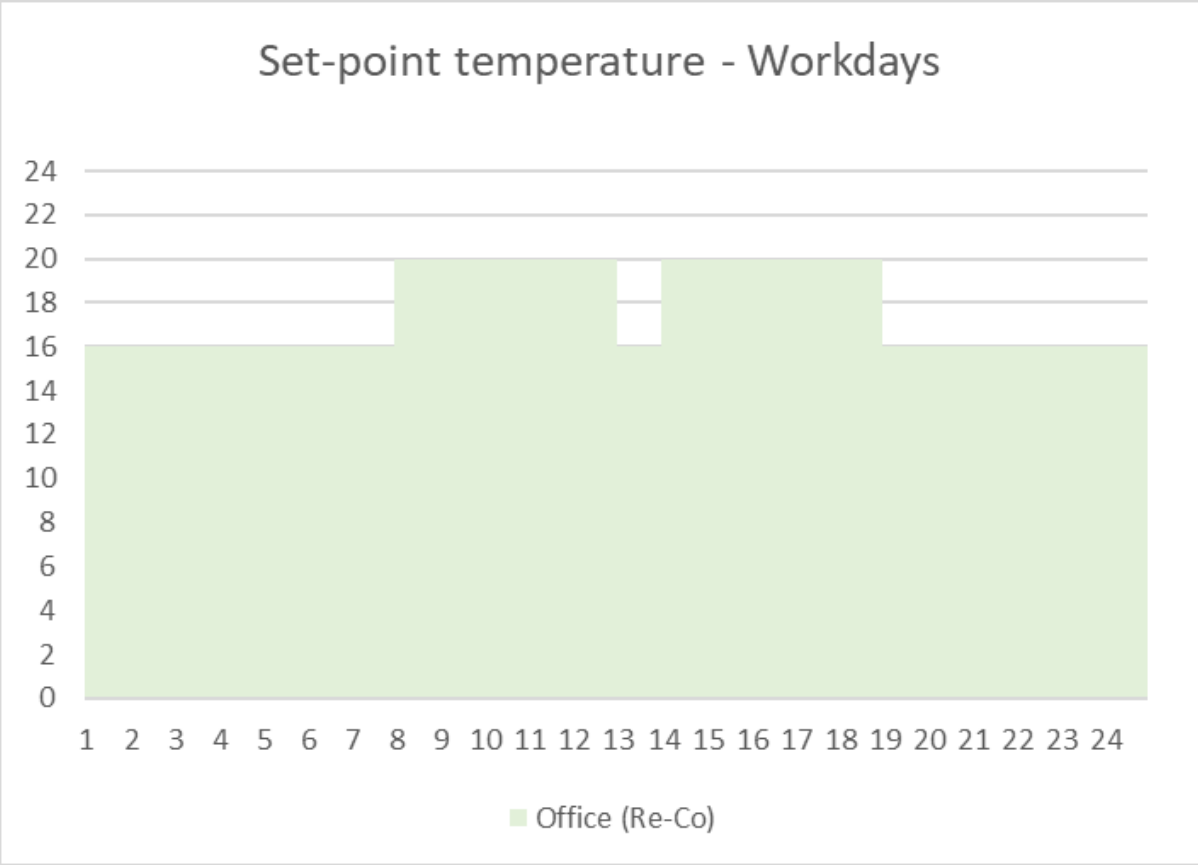
The measures

Three main measures were defined and performed:

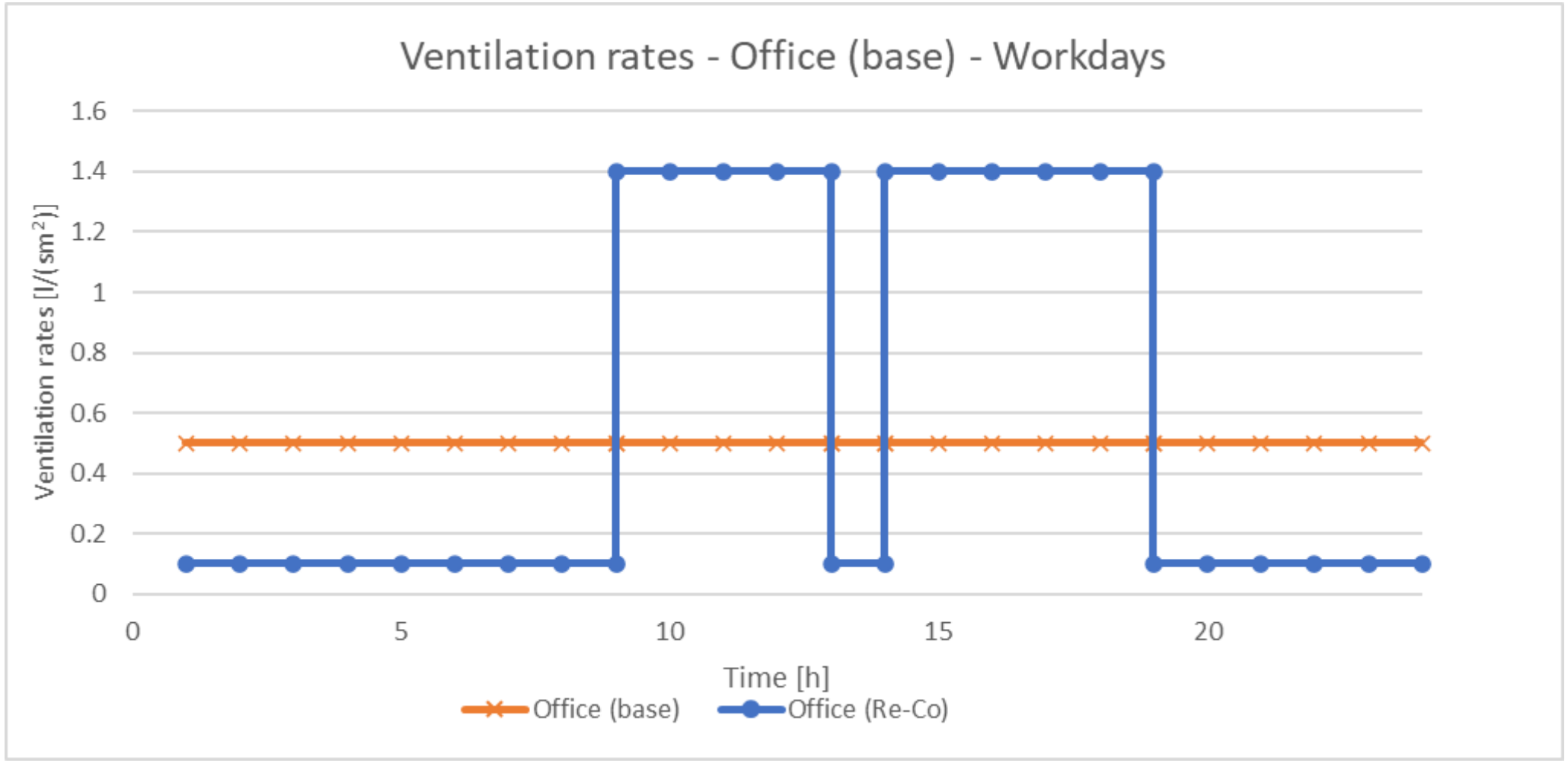
- Modification of the heating schedule according to the actual office occupation
- Modification of the heating control system. The on/off zone control was substituted by a proportional-integral (PI) room control system
- Modification of the ventilation flow rates and heating system working schedules

The measures
Heating schedules

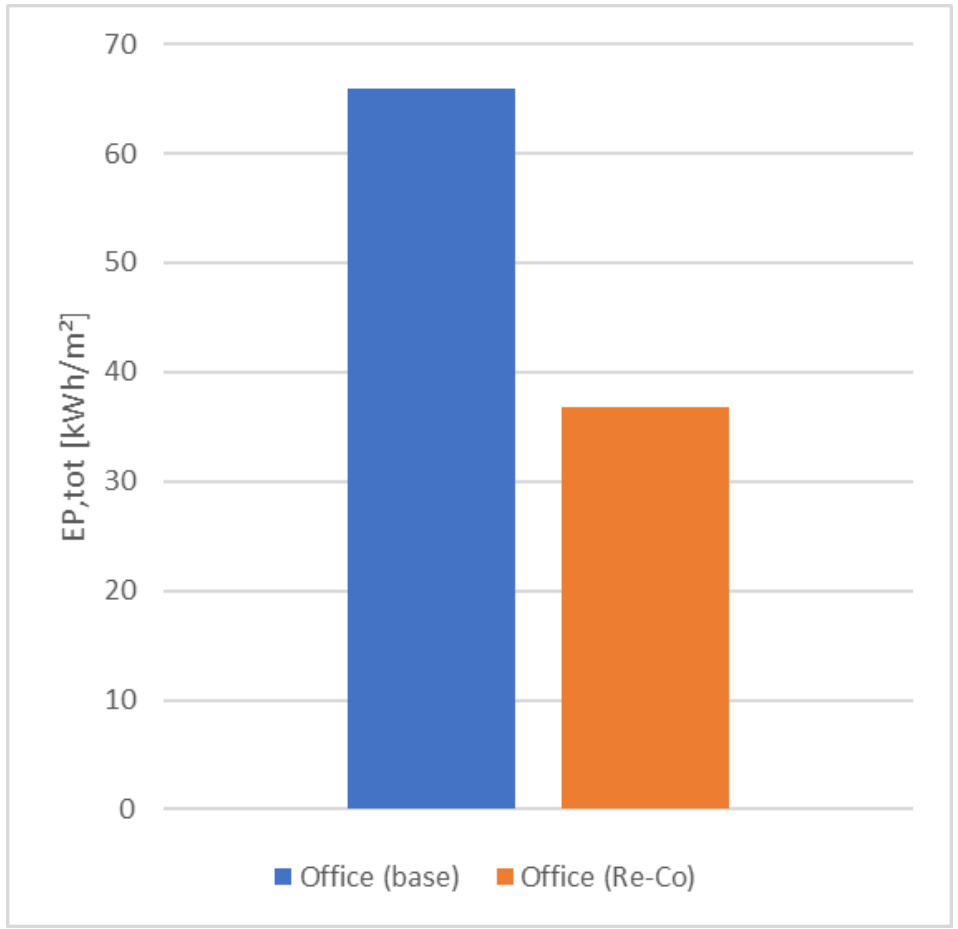


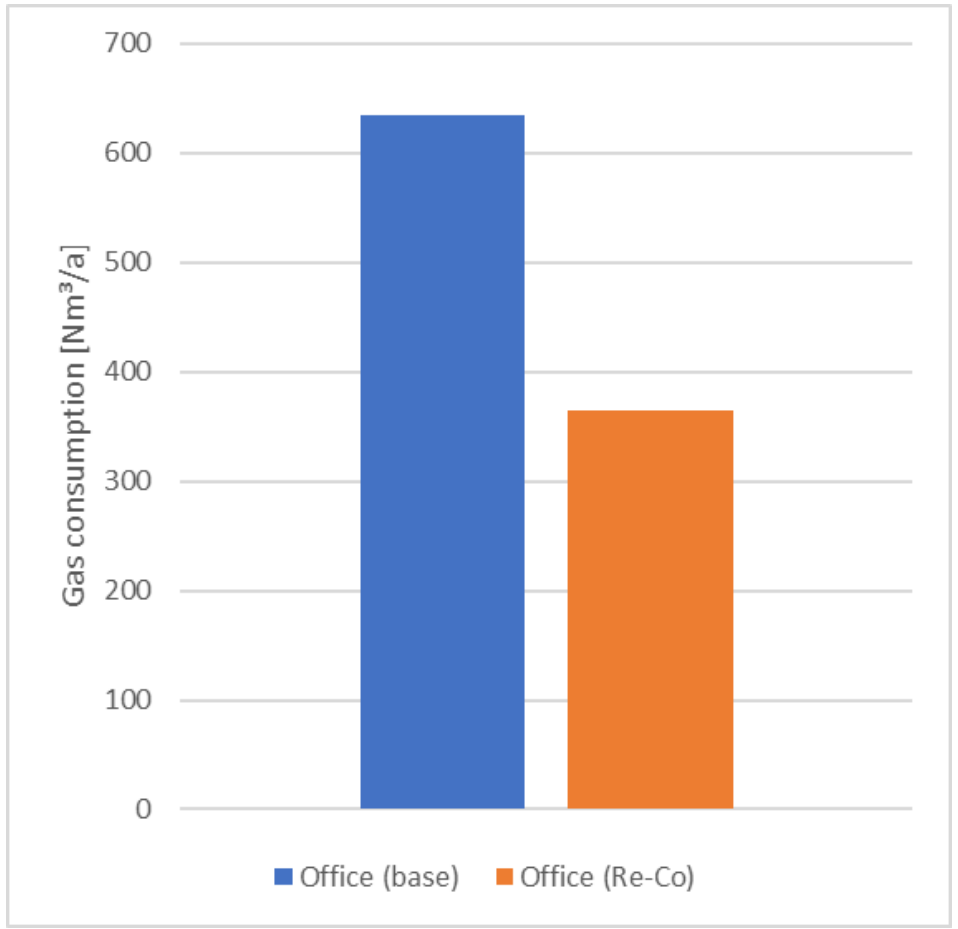


The measures
Ventilation rates



The results – Energy consumption





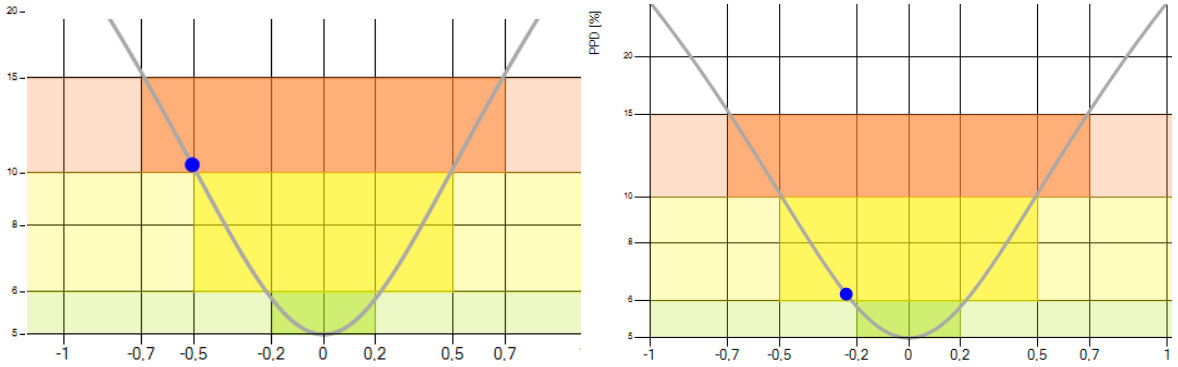
The results – Economic impact

Measure	Description	$EP_{H,tot}$ [kWh/m²]	CO_2 [kg/a]	Payback time [a]
0	Baseline	65,92	1327	-
1	Modification of the heating schedule according to the actual office occupation	56,34	1141	0
2	Modification of the heating emission control system (from zone on/off, to room PI)	45,91	938	2,6
3	Modification of the ventilation flow rate according to the actual office occupation and to the IAQ needs)	49,56	1010	0
4	Measures 1 + 2 + 3	36,75	761	1,8

The results – User's comfort

The operative temperature analysed in the offices are, after the Re-Co more in line with the expected temperatures

- The PMV and PPD for the north office, calculated before and after the Re-Co, shows an increase of the thermal comfort



The ventilation rates, after the Re-Co, are in compliance with the minimum requirements for indoor air quality.

The daily ventilation flow rate is almost identical in the base and after the Re-Co. Nevertheless, the use of occupancy-based ventilation profiles grant both energy savings and IAQ comfort.

The noise and light comfort were already verified before the Re-Co

Re-Commissioning examples

Four examples of recommissioning results are presented following these steps:

- Presentation of the case study, highlight of the main deficiencies and possible improvements

- Analysis of the results from an economic and environmental point of view

Re-Commissioning – Adult education centre

Case study

Centre St-Michel is an education centre for adults in downtown Sherbrooke. Built in 1948, the building has 5,700 m^2 of floor area and provides courses for an average of 860 students daily. The annual energy consumption cost was about $120300 before the RCx was done. After completion in 2009, the RCx reduced the bill by 11% and focused mainly on the following electromechanical systems:

- Natural gas boiler of 590 kW
- Fifteen ventilation systems totalizing 13200 l/s
- Cooling system of 232 kW

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-45/2011E

Re-Commissioning – Adult education centre
Measures

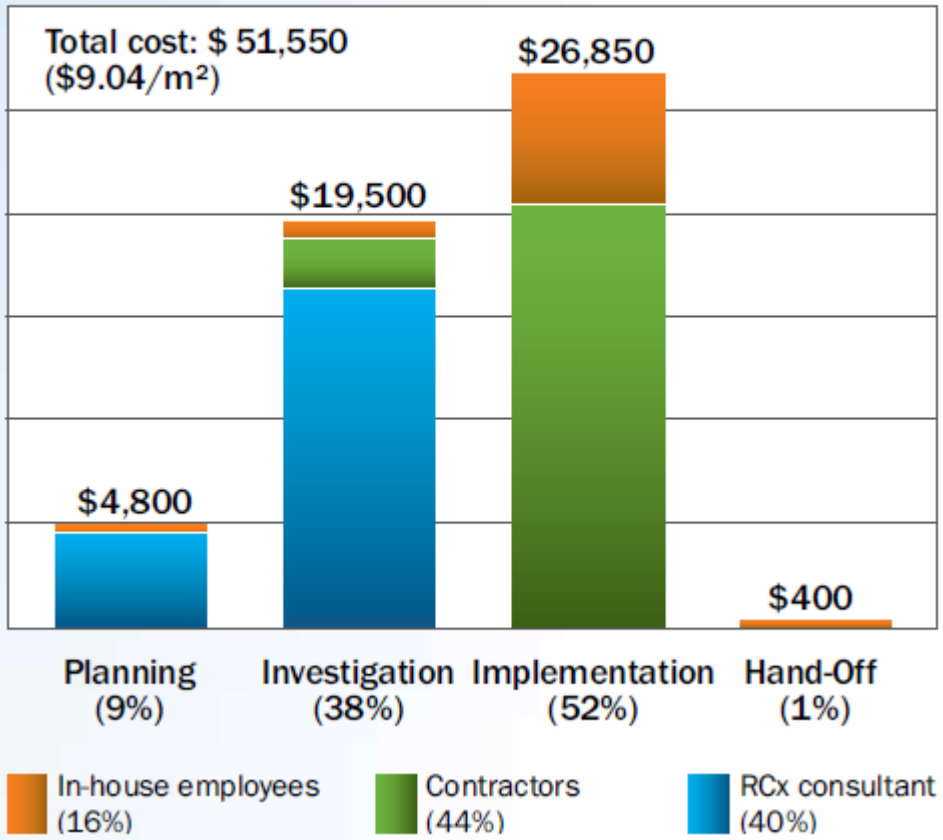
RCx winning measures		Annual savings
1	**Correction of deficiencies in steam traps and control valves** Implementation of a preventive maintenance program for steam traps and control valves that includes a monitoring log and the replacement of all defective equipment. Annual natural gas savings of 12,000 m^3. Cost: $7,800 | Payback: 1.1 year	450 GJ/year $7,200/year
2	**Addition of a deadband between the heating and cooling setpoints** Insertion of a deadband between the heating and cooling modes. Annual savings of 6,500 kWh of electricity and 1,500 m^3 of natural gas. Cost: $480 | Payback: 0.3 year	80 GJ/year $1,550/year
3	**Addition of a control point for the burner** Connected the burner to the centralized control system and implemented a control logic based on outside temperature. Annual natural gas savings of 1,010 m^3. Cost: $500 | Payback: 0.9 year	38 GJ/year $570/year
	Ten other RCx measures Cost: $18,000 | Payback: 4.5 years	195 GJ/year $3,980/year

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-45/2011E

Re-Commissioning – Adult education centre

Results

Cost breakdown



Results

- Energy savings[1]: 763 GJ/year (12%)
  (gas: 644 GJ, electricity: 119 GJ)
- Monetary savings[2]: $13,300/year
- GHG reduction: 42 t CO_2 e/year
  (equivalent to 8 cars)
- Simple payback[3]: 3.9 years

[1] *Savings verified by an independent third party in accordance with the International Performance Monitoring & Verification Protocol (IPMVP) and standardized according to weather conditions.*

[2] *Monetary savings do not include non-energy impacts (NEIs) such as extended service life of equipment or increased comfort for tenants.*

[3] *Includes all costs for the four phases of the project.*

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-45/2011E

Re-Commissioning – Elementary school

Case study

The Our Lady of Peace Elementary School, built in 1968, comprises 1950 m^2 of floor area on one single floor. The building accommodates children in kindergarten up to Grade 6. Before the RCx, the annual energy bill was about $44500. After completion in 2010, the RCx reduced the bill by 17% and focused mainly on the following electromechanical systems:

- Natural gas boiler with 225 kW capacity
- Electric boiler with 150 kW capacity
- Ventilation system with a capacity of 5700 l/s
- Cooling system with a capacity of 42 kW

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-46/2011E

Re-Commissioning – Elementary school

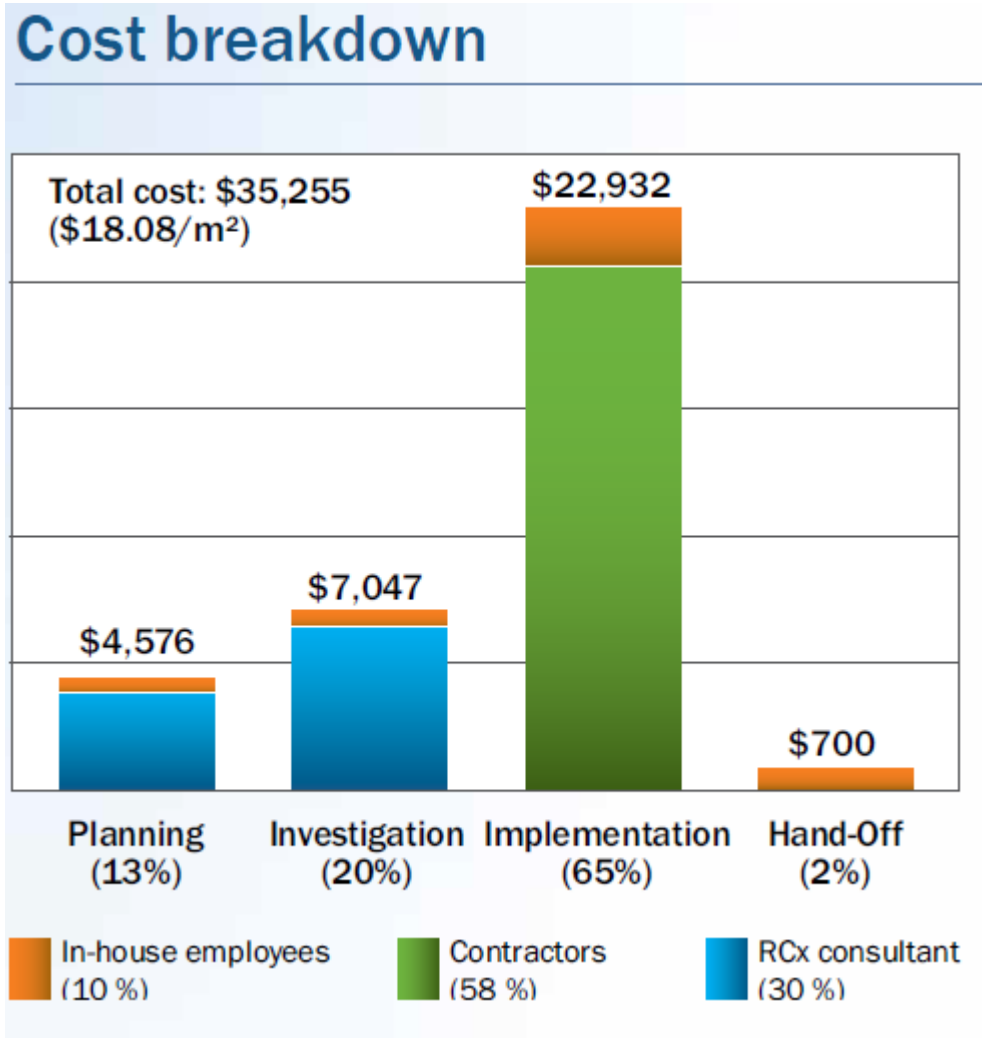
Measures

RCx winning measures		Annual savings
1	**Optimization of stop/start commands for the ventilation unit and the main evacuators** Operate the ventilation system and the main evacuators on a schedule rather than in continuous 24/7. Ensure that the fresh air flow is controlled based on the working evacuators. Annual savings of 36,113 kWh of electricity and of 8,129 m^3 of natural gas. Cost: $10,700 | Payback: 1.5 year	438 GJ/year $7,000/year
2	**Restart electric boiler** Restart the electric boiler for natural gas use savings. Electricity consumption increased by 178,500 kWh and consumption of natural gas reduced by 21,000 m^3. Cost: N/A | Payback: N/A	155 GJ/year -$1,665/year
3	**Decrease the temperature during unoccupied periods** Decrease the temperature in rooms at night and on weekends (from 22°C to 18°C) using sensors in strategic rooms. Annual savings of 1,710 m^3 of natural gas. Cost: $4,800 | Payback: 4.5 years	65 GJ/year $1,065/year
	Seven other RCx measures Cost: $5,380 | Payback: 4.8 years	87 GJ/year $1,115/year

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-46/2011E

Re-Commissioning – Elementary school

Results



Results

- Energy savings[1]: 745 GJ/year (37%)
- Monetary savings[2]: $7,515/year
- GHG reduction: 41 t CO_2 e/year
  (equivalent to 7 cars)
- Simple payback[3]: 4.7 years

[1] *Savings verified by an independent third party in accordance with the International Performance Monitoring & Verification Protocol (IPMVP) and standardized according to weather conditions.*

[2] *Monetary savings do not include non-energy impacts (NEIs) such as extended service life of equipment or increased comfort for tenants.*

[3] *Includes all costs for the four phases of the project.*

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-46/2011E

Re-Commissioning – Office tower

Case study

Built in 1965, the Royal Bank office building in downtown Winnipeg is one of the first modern high-rises built in Manitoba. The 17-storey building of 20000 m^2 accommodates about 1000 employees and its annual energy bill before the RCx was about $294000. Completed in 2009, the RCx reduced the bill by 20% and focused mainly on the following electromechanical systems:

- Two natural gas boilers, each with a capacity of 2930 kW
- Ten air handling units with a total capacity of 69500 l/s
- Two chillers with a total capacity of 1512 kW

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-47/2011E

Re-Commissioning – Office tower

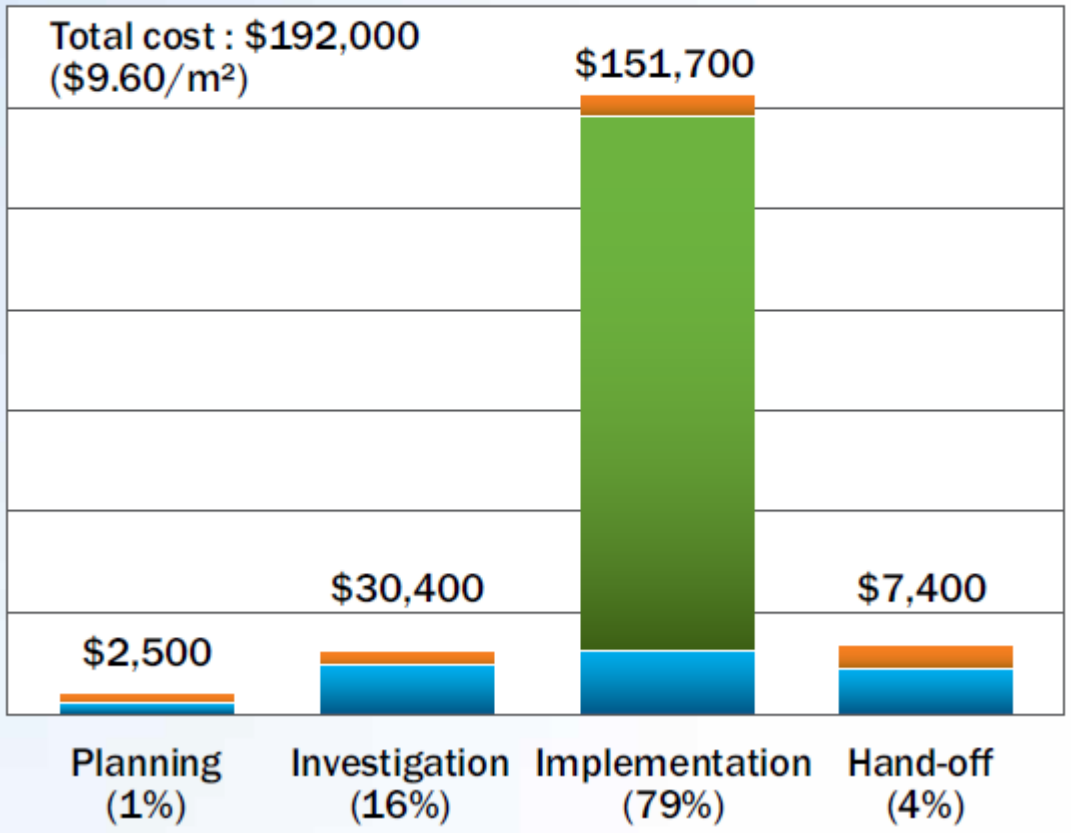
Measures

RCx winning measures		Annual savings
1	**Optimization of ventilation systems** Both ventilation systems were functioning continuously at constant loads. The operating hours were reduced and re-scheduled based on occupancy rates and outdoor temperatures, resulting in natural gas and electricity savings. Cost: $97,500 | Payback: 2.9 years	3,727 GJ/year $33,075/year
2	**Installation of CO_2 sensors** This measure regulates the return air CO_2 levels and modulates the opening of outside air dampers when CO_2 concentrations rise, resulting in natural gas savings. Cost: $30,000 | Payback: 1.8 years	1,779 GJ/year $16,300/year
3	**Setpoints modification and night setback** The direct digital command (DDC) is reprogrammed to maintain a 23°C (74°F) cooling setpoint and a 21°C (70°F) heating setpoint during daytime and to reduce night loads, resulting in natural gas savings. Cost: $7,900 | Payback: 2.9 years	298 GJ/year $2,700/year
	Other RCx measures Cost: $56,600 | Payback: 8.2 years	848 GJ/year $6,925/year

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-47/2011E

Re-Commissioning – Office tower
Results

Cost breakdown



Results

- Energy savings[1] (75% natural gas, 25% electricty) — 6,652 GJ/year (25%)
- Monetary savings[2] — $59,000/year
- GHG reduction (equivalent to 66 cars) — 363 t CO_2 e/year
- Simple payback[3] — 3.3 years

[1] *Savings verified by an independent third party in accordance with the International Performance Monitoring & Verification Protocol (IPMVP) and standardized according to weather conditions.*

[2] *Monetary savings do not include non-energy impacts (NEIs) such as extended service life of equipment or increased comfort for tenants.*

[3] *Includes all costs for the four phases of the project.*

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-47/2011E

Re-Commissioning – Office building
Case study

About 345 occupants work daily at the CRA Building, a five-storey building of 8,175 m^2 built in 1995 and located on the Selkirk Waterfront in Victoria. The building houses a number of provincial government department tenants, including BC's forest fire command centre, which operates 24/7 during the peak fire season. Annual energy consumption was about $150000 before the RCx was done. When completed in 2008, the RCx, focusing mainly on the following electromechanical systems, had reduced
the bill by 26%:

- Two natural gas boilers, each with a 325 kW capacity
- Two air handling units with a total capacity of 39200 l/s
- Two chillers with a total capacity of 281 kW

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-48/2011E

Re-Commissioning – Office building

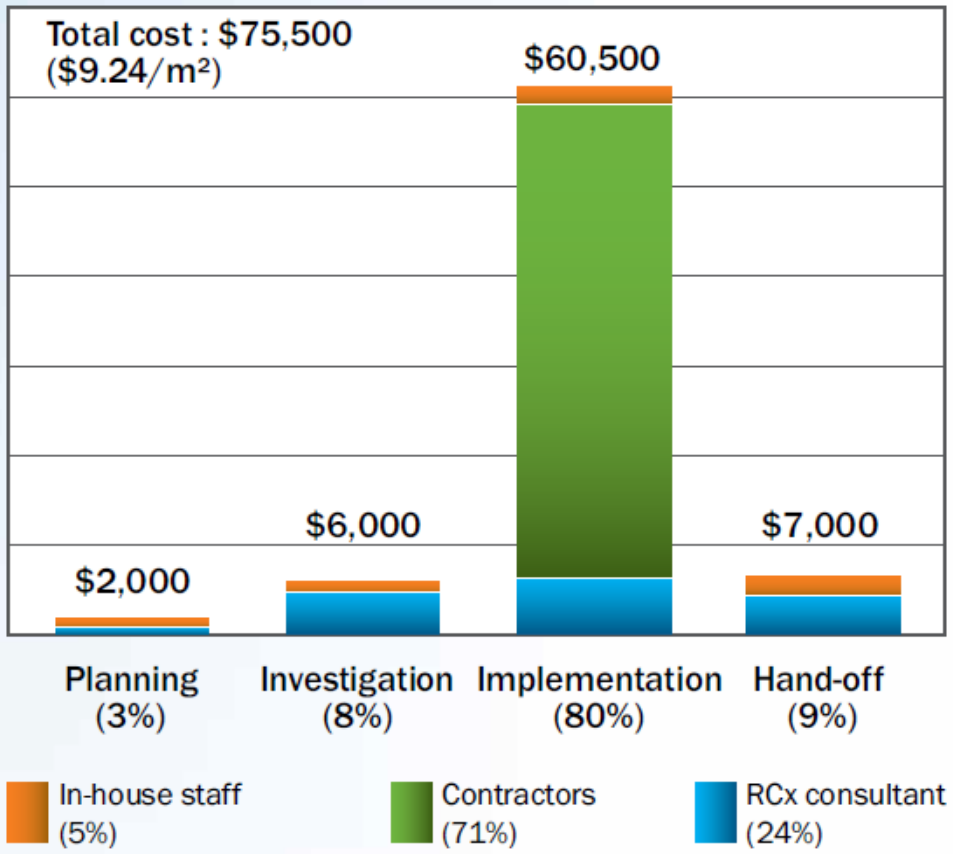
Measures

RCx winning measures		Annual savings
1	**Simultaneous heating and cooling** Systems were consuming large quantities of natural gas during the summer months. Outdoor air lockout with a temperature prediction algorithm was installed to lock out heating systems during warmer weather. Cost: $6,400 | Payback: 1.1 year	529 GJ/year $5,800/year
2	**Optimization of variable air volume (VAV) systems** Adjusted minimum flows and controller logic on each VAV box optimized operation and limited the use of excessive ventilation. Cost: $3,200 | Payback: 0.8 year	380 GJ/year $4,085/year
3	**Reset of air temperature supply** Supply air temperature reset program implemented. Cost: $1,500 | Payback: 0.5 year	250 GJ/year $2,750/year
	Eleven other RCx measures Cost: $49,400 | Payback: 1.9 year	1,883 GJ/year $26,365/year

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-48/2011E

Re-Commissioning – Office building
Results

Cost breakdown



Results

- Energy savings[1]: 3,042 GJ/year (30%)
  (60% natural gas and 40% electricity)
- Monetary savings[2]: $39,000/year
- GHG reduction: 164 t of CO_2 e/year
  (equivalent to 30 cars)
- Simple payback[3]: 1.9 year

[1] *Savings verified by an independent third party in accordance with the International Performance Monitoring & Verification Protocol (IPMVP) and standardized according to weather conditions.*

[2] *Monetary savings do not include non-energy impacts (NEIs) such as extended service life of equipment or increased comfort for tenants.*

[3] *Includes all costs for the four phases of the project.*

Source: National Resources Canada, CammetENERGY, Catalogue no.: M154-48/2011E

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Thanks for your attention!

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033819