TRAINEE TowaRd market-based skills for sustAINable Energy Efficient construction

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 785005

Acronym: TRAINEE

Grant Agreement Number 785005

HORIZON 2020

# POST OCCUPANCY EVALUATION

## - Piloting Methodology's Report-

-

Deliverable 3.4

Date: 30.04.2020

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## DISCLAIMER



## ACKNOWLEDGEMENT

This document is a deliverable of TRAINEE project. This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement Nº 785005.

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## Abbrevations

| | |
|---|---|
| AERM | Energy Agency of the Republic of North Macedonia |
| BACS | Building Automation Control Systems |
| BEMS | Building Energy Management Systems |
| BMS | Building Management System |
| EPC | Energy Performance Certificate |
| FM | Facility Management |
| HOA | Home Owner Associations |
| HVAC | Heating Ventilation and Air Conditioning |
| MURBs | Multi-Unit Residential Buildings |
| POE | Post Occupancy Evaluation |
| TRAINEE | Toward market-based skills for sustainable energy efficient construction |
| RES | Renewable energy sources |

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# 1 Report Summary

The purpose of this report is to present benefits of Post Occupancy Eevaluatiom (POE) to stakeholders so they could think about POE as being an inseparable part of the building process. Very often stakeholders don't even realize the power which the POE can play during different stages of a life cycle of the building. Performance evaluation of new or retrofitted buildings can serve to show whether promised benefits are actually delivered, potentially speeding their adoption in the sector.

This Report of Post Occupancy Evaluation is developed in accordance with the POE Methodology, as deliverable of the project TRAINEE. The POE methodology was applied by the project team on four buildings: two buildings constructed by companies with certified workers for implementation of energy efficiency measures participated in the previous project BEET, and other two buildings constructed by companies whose workers have no record for skills to proper implement energy efficient measures. The buildings are finished in the period after 2014 meaning and they have documentation for energy efficiency according the Official Gazette of the Republic of Macedonia No. 94 from 04.07.2013. The report will be published and obtained results and conclusions will be promoted on the conference with representatives from all relevant shareholders.

# 2 Delivery, Operational, Business and Functional Performance Review

## 2.1 Introduction to results

The activities related to POE were realized in the period of March and April 2020, in accordance with the POE Methodology. The challenge was the situation with pandemic. Direct contacts with stakeholders were avoided and the communication was on-line. For collecting data, especially in the process of choosing the buildings, the Energy Agency of the Rupublic of North Macedonia (AERM) and municipalities from Skopje were contacted. The adaptation to restricted working hours and part time job of the relevant administrative employees was required. It was decided the analyzed buildings to be from municipalities Karposh and Aerodrom, having the most number of energy efficient buildings.

Two chosen buildings are from Municipality Aerodrom and two from Municipality Karposh. The buildings are anonymously presented in the report, but the collected data and calculations as a part of the POE are available for relevant entities on request. The team involved in POE is MSc Igor Panchevski gee and MSc Zhanina Stamenkova gce, both authorized energy auditors. Realization of the activities is as presented according Methodology:

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| 1. Initial contact | The initial contact was made with AERM and the chosen municipalities (Aerodrom and Karposh) for providing adequate buildings for POE. After the selection of buildings, the contact was made with the Communication with HOA/President of the house council for each building. The contacts were made per e-mail and mobile phone. Duration: from 2th till 6th March 2020. |
| 2. Pre-visit meeting | Due to restriction measures activated with the pandemic, the pre-visit meetings with engineers and architects were replaced with on-line clarifications. Duration: 9th till 13th of March. |
| 3. First site visit | Site visits, semi-structured interviews with occupants, check on-site records, semi structured interview with occupiers, observation and walks through buildings were also restricted and adapted to the pandemic situation, but sufficient data for planned POE were collected, regarding envelope, windows, positioning regarding to shadows, ventilation, heating/cooling and lighting.<br>Duration: 9th till 13th of March. |
| 4. Review of basic energy data | Electricity and heating bills were collected with the help of engineers from the construction companies, who have contacts of the inhabitants, their clients, ready to support and take part in the POE. Duration: 16th till 20th of March. |
| 5. Survey of design | Design assessment is based on as-built documentation and drawings, Statements of compliance for energy efficiency (part of the design documentation and mandatory document for Construction permit) and Energy Certificates (mandatory document for Usage permit). It is performed analysis of existing questionnaire and discussion with occupants. Duration: 23th till 27th of March. |
| 5. Energy Analysis | Energy Performance Rating assessment is following the POE methodologies and methods. It is based on the survey of design documentation and review of basic energy data (bills). Duration: 16th till 20th of March. |
| 7. Occupant Questionnaire distribution | The questionnaire was delivered to inhabitants of 4 analyzed buildings and the results are presented for each case as Case studies. Duration: from 30th of March till 10th of April. |
| 8. Survey Analysis | The analyses were discussed and clarified among the representatives of the buildings, included from the beginning, and the project team, separately for each building, on-line. Duration: 13th till 16th of April. |
| 9. Results of POE | Results of the adjusted post-occupancy evaluation with recommendations are summarised in the Report. Duration: 22th till 30th of April. |

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## 2.2 Case study 1 - Building AS

Building AS is finished in 2015. The building is with 1.595m$^2$ heated areas, consists of ground floor and 5 floors and has 30 flats. Heating is central, provided from company BEG. Cooling is provided with air-conditioners. Flats are naturally ventilated. The building is relatively new and is in good condition regarding construction, common spaces and installations. The flats of interviewed owners are with 44m$^2$, 48m$^2$, 62m$^2$ and 64m$^2$.

**RESULTS:**

**Comfort in general:** All of interviewed inhabitants declared that they can control the inside comfort.

**Quality of the air inside:** 75% are satisfied with the quality of the air, they feel it as fresh and dry. Air movement, while closed doors and windows, is reported from 50% of inhabitants.

**Thermal comfort in winter:** Building AS is with energy class „A", with nominal demand of heating energy $q_{H,nd}$ =20,64 kWh/m$^2$ annually. The calculation corresponds to 20°C inside temperature in winter and 0,5 exchanges of air in one hour, as regulated. According the design documentation, the final energy needed for heating is 22,89 kWh/m$^2$ annually, obtained from central heating. The average reported temperature inside in winter is 25°C . All interviewed inhabitants find the temperature in winter comfortable. The analyze of the bills for heating indicates that the final energy for heating is corresponding to temperature of 25°C and two exchanges of air per hour or correspondent combination of temperature and natural ventilation.

**Thermal comfort in summer:** The average temperature in flats, in summer, due to cooling, is 24°C that is less than recommended healthy 26°C. The cooling is average 6h/day in summer months. All of interviewed have blinds on the windows for summer and air-conditioners for cooling.

**Acoustic comfort:** Majority is satisfied with acoustic comfort. 50% are not disturbed from outside noise and 75% from background noise. 25% do not know.

**Light comfort:** The light comfort is average taking into consideration that 75% declared lack of natural light. All of interviewed have blinds on the windows for protection of summer light and heat. All declared that the light in common rooms is medium. 75% are satisfied with lightning in their flats/living rooms.

**Ventilation:** 75% are not controlling the natural ventilation. All of interviewed are drying clothes inside the flat and are not opening the windows during the night. 25% are ventilating non-stop. 50% are ventilating with sash windows.

**Costs:** The costs for heating are about (1.100-1.600)den or (17,8-25,9)euros monthly pro flat. The costs for electricity are about (1.300-2.500)den or (21,0-40,5)euros monthly pro flat. 50% of the questioned inhabitants declared that they can influence the costs. All inhabitants declared that the costs for heating and electricity are not high.

The analyzed results of the questionnaires, more detailed, follow:

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|---|---|---|
| 1) | How much time you stay in the building (Hours >1 1-2 3-4 5-6 7-8 >8) ? | All of the interviewed inhabitants declared that they are more than 8h in the building. |
| 2) | Does the quality of the air have a negative effect on your work/living performance? | 75 % of the interviewed inhabitants declared that quality of the air inside has no negative effect on work/living. |
| 3) | Do you feel the air fresh or stale? | 75 % of the interviewed inhabitants declared that they feel the air as fresh. |
| 4) | Do you feel the air humid or dry? | 75% feel the air dry. The rest 25% do not know. |
| 5) | Do you feel air movement? | 50% feel air movement inside the flats. |
| 6) | Do you have control over ventilation? | 75% are not controlling the ventilation. |
| 7) | What is the indoor temperature in winter? | The average inside temperature in winter is 25°C. Maximal reported temperature is 30°C, minimal 22°C. |
| 8) | Does the temperature have a negative effect on your work/living performance? | 75% declared that the inside temperature has no negative effect on their living/performance. |
| 9) | Is the temperature in winter too high or too low? | 100% declared that the temperature in winter is comfortable. |
| 10) | Does the distraction from noise have a negative effect on your work/living performance? | 50% declared that they are not distracted from the noise, 50% are not sure about that. |
| 11) | Is there significant distraction from noise outside the space with closed windows? | 50% declared that there is no significant distraction from outside noice, with closed windows. |
| 12) | Is there significant distraction from background noise? | 75% feel no significant distraction from background noice. |
| 13) | What is the light level in the common areas, corridors etc. (low, medium, high)? | 100% declared that the light in common areas is medium. |
| 14) | Does the quality of the light in the living room have a negative effect on you? | 75% declared that the light in their livingroom has no negative effect on them and 25% that it has negative effects. |
| 15) | Is there too much or too little natural light? | 75 % declared that there is too little natural light in the flats and 25% feel it as too much. |
| 16) | Are you using blinds/shutters for effective control of natural light? | 100% have blinds/shutters on the windows/balcony doors. |
| 17) | Do you dry your clothes inside the apartment? | 100% dry clothes inside. |
| 18) | How do you ventilate your apartment: a) sash window; b) wide open windows from time to time? | 50% are naturally ventilating the flat with wide open windows and 50% with sash windows. |
| 19) | How many times do you ventilate your home? | 25% are ventilating non stop and 75% are ventilating 2-3 times a day. |
| 20) | Do your windows stay open during the night? | 100% declared that the windows are not opened during the night. |
| 21) | What is the air temperature in summer when cooling system is ON? | The average inside temperature in summer is 24°C. Maximal reported temperature is 28°C, minimal 21°C. |
| 22) | How many hours per day your cooling system is ON during the summer time? | In average the cooling system is ON average 6 hours per day: maximal 15h, minimal 2 h. |
| 23) | Do you consider your costs for electricity as high? | 100% do not consider the costs for elecrticity high. |
| 24) | How much do you pay for electricity monthly? | Average 1.725den (28€)/flat montly or 380 den (6,2€)/m2 anually. |
| 25) | Do you consider your costs for heating as high? | 100% do not consider the costs for heating high. |
| 26) | How much do you pay for heating monthly? | Average 1.325den (21,5€)/flat montly or 303 den (4,9€)/m2 anually. |
| 27) | Do you think that you can influence on your costs? | 50% declared thay can influence their costs. |
| 28) | Do you think that you can influence on your comfort? | 100% declared thay can influence the living comfort. |

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## 2.3 Case study 2 - Building AG

Building AG is finished in 2015. The building is with 7.671m$^2$ heated areas, consists of basement, ground floor, 8 floors and penthouse and has 112 flats. Heating is central, provided from company BEG. Cooling is provided with air-conditioners. Flats are naturally ventilated. The Building is with high quality and in good condition, including installations. The flats of interviewed owners are with 36m$^2$ and 44m$^2$.

**RESULTS:**

**Comfort in general:** 67% of interviewed inhabitants declared that they can control the inside comfort.

**Quality of the air inside:** 100% are satisfied with the quality of the air, they feel it as fresh and 33% as dry. Air movement, while closed doors and windows, is reported from 100% of inhabitants.

**Thermal comfort in winter:** Building AG is with energy class „A", with nominal demand of heating energy $q_{H,nd}$=21,54 kWh/m$^2$ annually. The calculation corresponds to 20°C inside temperature in winter and 0,5 exchanges of air in one hour, as regulated. According the design documentation, the final energy needed for heating is 24,76 kWh/m$^2$ annually. The average reported temperature inside in winter is 23°C. The analyze of the bills for heating are indicating that the final energy for heating is corresponding to temperature of 23°C and 1,3 exchanges of air per hour or correspondent combination of temperature and natural ventilation. 67% of interviewed inhabitants find the temperature in winter as comfortable and 33% that it is too high.

**Thermal comfort in summer:** The average temperature in flats, in summer, due to cooling, is 24°C that is less than recommended healthy 26°C. The cooling is average 6h/day in summer months. All of interviewed have blinds on the windows for summer and air-conditioners for cooling.

**Acoustic comfort:** 67% are sensitive to noise. 100% are not disturbed from outside noise and 67% from background noise.

**Light comfort:** 100% declared lack of natural light. All of interviewed have blinds on the windows for protection of summer light and heat. 67% declared that the light in common rooms is medium. 67% are satisfied with lightning in their flats/living rooms. The light comfort is average taking into consideration that all declared lacking natural light

**Ventilation:** 67% are not controlling the natural ventilation and are not opening the windows during the night. All of interviewed are drying clothes inside the flat. 67% are ventilating more than 3 times a day. 67% are ventilating with sash windows.

**Costs:** The costs for electricity are about 1.117den (18€) pro flat monthly. The costs for heating are average 725den (11,8€) per flat monthly, 12 months. 67% of the questioned inhabitants declared that they can influence the costs. 67% of inhabitants are finding that the costs for electricity are not high and 100% of inhabitants have opinion that cost for heating are low.

The analyzed results of the questionnaires, more detailed, follow:

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| | | |
|---|---|---|
| 1) | How much time you stay in the building (Hours >1 1-2 3-4 5-6 7-8 >8) ? | 67% of the interviewed inhabitants declared that they are more than 8h in the building and 33% between 5-6h. |
| 2) | Does the quality of the air have a negative effect on your work/living performance? | 100% of the interviewed inhabitants declared that quality of the air inside has no negative effect on work/living. |
| 3) | Do you feel the air fresh or stale? | 100% of the interviewed inhabitants declared that they feel the air as fresh. |
| 4) | Do you feel the air humid or dry? | 33% feel the air dry and 67% do not know. |
| 5) | Do you feel air movement? | 100% feel air movement inside the flats. |
| 6) | Do you have control over ventilation? | 67% are not controlling the ventilation. |
| 7) | What is the indoor temperature in winter? | The average inside temperature in winter is 23°C. Maximal reported temperature is 26°C, minimal 20°C. |
| 8) | Does the temperature have a negative effect on your work/living performance? | 100% declared that the inside temperature has no negative effect on their living. |
| 9) | Is the temperature in winter too high or too low? | 67% declared that the temperature in winter is comfortable and 33% that is too high. |
| 10) | Does the distraction from noise have a negative effect on your work/living performance | 67% declared that they are distracted from the noise and 33% are not distracted. |
| 11) | Is there significant distraction from noise outside the space with closed windows? | 100% declared that they are not distracted from outside noise. |
| 12) | Is there significant distraction from background noise? | 67% feel no significant distraction from background noice. |
| 13) | What is the light level in the common areas, corridors etc. (low, medium, high)? | 67% declared that the light in common areas is medium and 33% that is low. |
| 14) | Does the quality of the light in the living room have a negative effect on you? | 67% declared that the light in their livingroom has no negative effect on them and 33% answered with YES. |
| 15) | Is there too much or too little natural light? | 100 % declared that there is too little natural light in the flats. |
| 16) | Are you using blinds/shutters for effective control of natural light? | 100% have blinds/shutters on the windows/ balcony doors. |
| 17) | Do you dry your clothes inside the apartment? | 100% dry clothes inside. |
| 18) | How do you ventilate your apartment: a) sash window; b) wide open windows from time to time? | 33% are naturally ventilating the flat with wide open windows and 67% with sash windows. |
| 19) | How many times do you ventilate your home? | 67% are ventilating more than 3 times a day and 33% are ventilating 3 times a day. |
| 20) | Do your windows stay open during the night? | 67% declared that the windows are not opened during the night. |
| 21) | What is the air temperature in summer when cooling system is ON? | The average inside temperature in summer is 22,7°C. Maximal reported temperature is 26°C, minimal 20°C. |
| 22) | How many hours per day your cooling system is ON during the summer time? | In average the cooling system is ON average 5 hours per day: maximal 4h, minimal 1h. |
| 23) | Do you consider your costs for electricity as high? | 67% consider the costs for elecrticity are not high. |
| 24) | How much do you pay for electricity monthly? | Average 1.117den (18€)/flat montly or 347 den (5,6€)/m2 anually. |
| 25) | Do you consider your costs for heating as high? | 100% consider the costs for heating are not high. |
| 26) | How much do you pay for heating monthly? | Average 725den (11,8€)/flat montly or 242den (3,9€)/m2 anually. |
| 27) | Do you think that you can influence on your costs? | 67% declared that can influence their costs. |
| 28) | Do you think that you can influence on your comfort? | 67% declared thay can influence the living comfort. |

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## 2.4 Case study 3 - Building AN

Building AN is finished in 2018. The building is with 8.310m$^2$ heated areas, consists of ground floor, 9 floors and penthouse, with 330 flats. Heating is central, provided from company BEK. Cooling is provided with air-conditioners. Flats are naturally ventilated. The Building is with high quality and in good condition, including installations. The flats of interviewed owners are with 41m$^2$, 42m$^2$ and 72m$^2$.

**RESULTS:**

**Comfort in general:** All interviewed inhabitants declared that they can control the inside comfort.

**Quality of the air inside:** 67% are satisfied with the quality of the air and declare it is fresh. Regarding humidity, majority cannot evaluate it and 33% consider the air is dry. Air movement, while closed doors and windows, is reported from 67% of inhabitants.

**Thermal comfort in winter:** Building AN is with energy class „A", with nominal demand of heating energy $q_{H,nd}$ =22,44 kWh/m$^2$ annually.

The calculated energy needed for heating is 26,40 kWh/m$^2$ annually. The calculation correspondents to 20°C inside temperature in winter and 0,5 exchanging of air in 1 hour, as regulated. The analyze of the bills for heating are indicating that the final energy for heating is corresponding to temperature of 27°C, the average reported value, and 1,5 exchanges of air per hour or correspondent combination of temperature and natural ventilation. They are all satisfied with the thermal comfort in winter with average 27°C inside.

**Thermal comfort in summer:** The average temperature in flats, in summer, due to cooling with air-conditioners, is 24°C that is less than recommended 26°C. The cooling is average 2,7h/day in summer. All of interviewed inhabitants have blinds on the windows.

**Acoustic comfort:** Majority is satisfied with acoustic comfort too. 67% are not distracted from outside noise and from background noise.

**Light comfort:** 100% of interviewed find that the light in common rooms is medium. 67% are satisfied with lightning in their flats/living rooms. 67%, declared lack of natural light, but 33% declared it is too much. All of interviewed have blinds on the windows for protection of summer light and heat.

**Ventilation:** 100% are not controlling the natural ventilation and are not opening the windows during the night. All of interviewed are drying clothes inside the flat. 67% are ventilating more than 3 times a day. 67% are ventilating with sash windows.

**Costs:** The costs for electricity are about (1.000-3.000)den or (16,2-48,6)euros, per flat. The costs for heating are about (785-1.400)den or (12,7-22,7)euros, per flat, 12 months. 33% declared that costs for electricity are high. All interviewed inhabitants consider that bills for heating are not high. All of the questioned inhabitants declared that they can influence the costs.

The analyzed results of the questionnaires, more detailed, follow:

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|---|---|---|
| 1) | How much time you stay in the building (Hours >1 1-2 3-4 5-6 7-8 >8)? | 33% of the interviewed inhabitants are more than 8h in the building, 34% are between 7-8h and 33% are between 5-6h. |
| 2) | Does the quality of the air have a negative effect on your work/living performance? | 67% of the interviewed inhabitants declared that quality of the air inside has no negative effect on work/living. |
| 3) | Do you feel the air fresh or stale? | 67% declared that they feel the air as fresh, 33% as stale. |
| 4) | Do you feel the air humid or dry? | 33% feel the air dry and 67% do not know. |
| 5) | Do you feel air movement? | 67% feel air movement inside the flats. |
| 6) | Do you have control over ventilation? | 100% are not controlling the ventilation. |
| 7) | What is the indoor temperature in winter? | The average inside temperature in winter is 27,5°C. 33% do not know. |
| 8) | Does the temperature have a negative effect on your work/living performance? | 67% declared that the inside temperature has no negative effect on their living. 33% do not know. |
| 9) | Is the temperature in winter too high or too low? | 100% declared that the temperature in winter is comfortable. |
| 10) | Does the distraction from noise have a negative effect on your work/living performance | 67% declared that they are not distracted from the noise and 33% are distracted. |
| 11) | Is there significant distraction from noise outside the space with closed windows? | 67% declared that they are not distracted from outside noise and 33% are distracted. |
| 12) | Is there significant distraction from background noise? | 67% feel no significant distraction from background noice. |
| 13) | What is the light level in the common areas, corridors etc. (low, medium, high)? | 100% declared that the light in common areas is medium. |
| 14) | Does the quality of the light in the living room have a negative effect on you? | 67% declared that the light in their livingroom has no negative effect on them and 33% do not know. |
| 15) | Is there too much or too little natural light? | 67% declared that there is too little natural light in the flats and 33% too much. |
| 16) | Are you using blinds/shutters for effective control of natural light? | 100% have blinds/shutters on the windows/ balcony doors. |
| 17) | Do you dry your clothes inside the apartment? | 100% dry clothes inside. |
| 18) | How do you ventilate your apartment: a) sash window; b) wide open windows from time to time? | 33% are naturally ventilating the flat with wide open windows and 67% with sash windows. |
| 19) | How many times do you ventilate your home? | 67% are ventilating more than 3 times a day and 33% are ventilating 1-2 times a day. |
| 20) | Do your windows stay open during the night? | 100% declared that the windows are not opened during the night. |
| 21) | What is the air temperature in summer when cooling system is ON? | The average inside temperature in summer is 22°C. 67% do not know. |
| 22) | How many hours per day your cooling system is ON during the summer time? | In average the cooling system is ON average 2,7 without big diference among interviewed. |
| 23) | Do you consider your costs for electricity as high? | 67% consider the costs for elecrticity low, 33% high. |
| 24) | How much do you pay for electricity monthly? | Average 1.667den (27€)/flat montly or 129den (2,1€)/m2 anually. |
| 25) | Do you consider your costs for heating as high? | 100% do not consider the costs for heating high. |
| 26) | How much do you pay for heating monthly? | Average 995den (16,2€)/flat montly or 231den (3,7€)/m2 anually. |
| 27) | Do you think that you can influence on your costs? | 100% declared that can influence their costs. |
| 28) | Do you think that you can influence on your comfort? | 100% declare that can influence the living comfort. |

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## 2.5 Case study 4 - Building SK

Building SK is finished in 2016. The building is with 2.263m$^2$ heated areas, consists of ground floor and 3 floors, with 22 flats. Heating and cooling is with heat pumps and ventilation is natural. The building is well preserved. The flats of interviewed owners are with area of 72m$^2$, 77m$^2$, 78 m$^2$, 120 m$^2$ and 185m$^2$.

**RESULTS:**

**Comfort in general:** All interviewed inhabitants declared that they can control the inside comfort.

**Quality of the air inside:** 67%, are satisfied with the quality of the air and 78% declare it is fresh. 44% consider the air is dry, 44% cannot evaluate it and 12% feel the air as humid. Air movement, while closed doors and windows, is reported from 67% of inhabitants.

**Thermal comfort in winter:** The energy class of the building is „B", with nominal demand of heating energy $q_{H,nd}$ =47,83 kWh/m$^2$ annually. The calculated energy needed for heating, obtained with heat pumps is calculated as 21,23 kWh/m$^2$ annually that corresponds to 20°C inside temperature and 0,5 exchanging of air in hour, as regulated. The analyze of the bills indicates that the final energy for heating is corresponding to temperature of 21°C, the average reported value, and 1,3 exchanges of air per hour or correspondent combination of temperature and natural ventilation. 67% are satisfied with the thermal comfort in winter with average 21°C inside and 33% declare that the temperature is too low.

**Thermal comfort in summer:** The average temperature in flats, in summer, due to cooling with air-conditioners, is 20°C that is less than recommended 26°C. The cooling is average 5h/day in summer. 89% of interviewed inhabitants have blinds on the windows.

**Acoustic comfort:** 89% of the interviewed is satisfied with acoustic comfort too. 44% are distracted from background noise.

**Light comfort:** About light comfort: 11%, declared lack of natural light, but 89% declared it is too much. 100% of interviewed find that the light in common rooms is medium. 78% are satisfied with lightning in their flat/living room. 89% of interviewed have blinds on the windows for protection of summer and heat.

**Ventilation:** 44% consider the air is dry, 22% humid and 44% does not know. 67% are not opening the windows during the night. 22% of interviewed are drying clothes inside the flat. 44% are ventilating 3/more times a day. 22% are ventilating with sash windows. 56% of them are not controlling the ventilation.

**Costs:** 56% interviewed inhabitants consider the bills for electricity high, but the costs for heating system are included. Costs for electricity are about 4.556den (74 euro) monthly pro flat, in 12 months. Costs for heating are about 2.944den (47,7€)/flat monthly. The costs for heating and electricity are in one bill because the heating is with heat pumps. 67% of the questioned inhabitants declared that they can influence the costs.

The analyzed results of the questionnaires, more detailed, follow:

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| | | |
|---|---|---|
| 1) | How much time you stay in the building (Hours >1 1-2 3-4 5-6 7-8 >8) ? | 67% of the interviewed inhabitants declared that they are more than 8h in the building and 33% between 7-8h. |
| 2) | Does the quality of the air have a negative effect on your work/living performance? | 67% of the interviewed inhabitants declared that quality of the air inside has no negative effect on work/living. |
| 3) | Do you feel the air fresh or stale? | 78% of the interviewed inhabitants declared that they feel the air as fresh. |
| 4) | Do you feel the air humid or dry? | 44% feel the air dry, 12% as humid and 44% do not know. |
| 5) | Do you feel air movement? | 67% feel air movement inside the flats. |
| 6) | Do you have control over ventilation? | 56% are not controlling the ventilation. |
| 7) | What is the indoor temperature in winter? | The average inside temperature in winter is 21°C. Maximal reported temperature is 25°C, minimal 18°C. |
| 8) | Does the temperature have a negative effect on your work/living performance? | 1% declared that the inside temperature has no negative effect on their living, 22% answered with YES and 77% do not know. |
| 9) | Is the temperature in winter too high or too low? | 67% declared that the temperature in winter is comfortable and 33% that is too low. |
| 10) | Does the distraction from noise have a negative effect on your work/living performance | 89% declared that they are not distracted from the noise and 11% are distracted. |
| 11) | Is there significant distraction from noise outside the space with closed windows? | 89% declared that they are not distracted from outside noise and 11% are distracted. |
| 12) | Is there significant distraction from background noise? | 44% feel no significant distraction from background noice. |
| 13) | What is the light level in the command areas, corridors etc. (low, medium, high)? | 100% declared that the light in common areas is medium. |
| 14) | Does the quality of the light in the living room have a negative effect on you? | 78% declared that the light in their livingroom has no negative effect on them and 22% are not shure. |
| 15) | Is there too much or too little natural light? | 11 % declared that there is too little natural light in the flats and 89% feel it as too much. |
| 16) | Are you using blinds/shutters for effective control of natural light? | 89% have blings/shutters on the windows/ balcony doors. |
| 17) | Do you dry your clothes inside the apartment? | 56% dry clothes in dryer, 22% inside and 22% outside. |
| 18) | How do you ventilate your apartment: a) sash window; b) wide open windows from time to time? | 78% are naturally ventilating the flat with wide open windows and 22% with sash windows. |
| 19) | How many times do you ventilate your home? | 44% are ventilating more than 3 times a day, 44% are ventilating 3 times a day and 12% 2 times a day. |
| 20) | Do your windows stay open during the night? | 67% declared that the windows are not opened during the night. |
| 21) | What is the air temperature in summer when cooling system is ON? | The average inside temperature in summer is 20°C. Maximal reported temperature is 24°C, minimal 16°C. |
| 22) | How many hours per day your cooling system is ON during the summer time? | In average the cooling system is ON average 5 hours per day: maximal 12h, minimal 2 h. |
| 23) | Do you consider your costs for electricity as high? | 56% consider the costs for elecrticity high. |
| 24) | How much do you pay for electricity monthly? | Average 4.556den (74€)/flat montly or 450 den (7,3€)/m2 anually. |
| 25) | Do you consider your costs for heating as high? | 67% do not consider the costs for heating high. |
| 26) | How much do you pay for heating monthly? | Average 2.944den (47,7€)/flat montly or 148 den (9,3€)/m2 anually. |
| 27) | Do you think that you can influence on your costs? | 67% declared that can influence their costs. |
| 28) | Do you think that you can influence on your comfort? | 100% declare that can influence the living comfort. |

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## 2.6 Discussion on summarized data

The discussion is on summarized data for all four buildings, as basic for recommendations and conclusion that follows, based on the data and insights collected for POE evaluation.

**Comfort in general:** 68,4% of all interviewed inhabitants declared that they can control the inside comfort. That means that the inhabitants have awareness how to enable comfortable conditions for living, but majority, 63,2% is not controlling the natural ventilation.

**Quality of the air inside:** Majority of the inhabitants in the four buildings is satisfied with the quality of the air inside. Regarding humidity, only 5,3% declare that the air is humid, in spite of the fact that majority of inhabitants explained that they are drying the clothes inside. This can be explained with higher inside temperature in winter, good insulation (relatively new buildings are analyzed) and sufficient natural ventilation that is preventing occurrence of mold. 47,4% declared feeling of movement of air, convection, that could be result of gaps in insulation of thermal bridges, especially around windows, in contact of different materials and in the places where the geometry changes.

| | | |
|---|---|---|
| Does the quality of the air have a negative effect on your work/living performance? | no | 73,7% |
| Do you feel the air fresh or stale? | fresh | 78,9% |
| Do you feel the air humid or dry? | dry | 47,4% |
| | humid | 5,3% |
| | do not know | 47,4% |
| Do you feel air movement? | yes | 47,4% |
| Do you have control over ventilation? | no | 63,2% |

**Thermal comfort in winter:** In 68,4% the indoor temperatures are higher than regulated, especially in the buildings AS, AG and AN, connected to central heating. But most of the inhabitants declared that the temperatures are comfortable. 26,3% of the inhabitants in this buildings consider temperatures too high, even temperatures of 30°C were reported. In the building SK, heated with thermal pumps, where the inhabitants have better control over temperatures and regime of work, the temperatures are lower, in some cases were reported temperatures lower than 20°C.

| | | |
|---|---|---|
| What is the indoor temperature ? | > 20°C | 68,4% |
| Does the temperature has a negative effect on your work/living performance? | no | 73,7% |
| Is the temperature in winter too high or too low? | comfortable | 78,9% |
| | too high | 26,3% |

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**Thermal comfort in summer:** The summer regime shows in 73,7% temperatures lower than recommended healthy temperature of 26°C that can be explained with insufficient knowledge on this item.

| | | |
|---|---|---|
| What is the air temperature in summer when cooling system is ON? | < 26°C | 73,7% |
| How many hours per day your cooling system is ON during the summer time? | > 4h | 42,1% |

**Acoustic comfort:** The results of analyze of the acoustic comfort shows are a little bit surprising. It was expected that the inhabitants will present unsatisfaction with acoustic comfort, but over 57% are not reporting distractions.

| | | |
|---|---|---|
| Does the distraction from noise have a negative effect on your work/living performance? | no | 68,4% |
| Is there significant distraction from noise outside the space with closed windows? | no | 78,9% |
| Is there significant distraction from background noise? | no | 57,9% |

**Light comfort:** The most significant finding is that in the buildings AS, AG and AN, the inhabitants are not satisfied with quantity of natural light in the flats. In the building SK the inhabitants are complaining on too much light.

| | | |
|---|---|---|
| What is the light level in the comman areas, coridors etc. (low, medium, high)? | medium | 94,7% |
| Does the quality of the light in the living room has a negative effect on you? | no | 73,7% |
| Is there too much or too little natural light? | too little | 47,4% |
| | too much | 52,6% |
| Are you using blinds/shutters for effective control of natural light? | yes | 94,7% |

**Ventilation:** 57,9% of the inhabitants are drying the clothes inside the flats. This percent should be higher, but the inhabitants in building SK have bigger flats and have dryers that diminish this score. According the bills and delivered final energy in the flats, the natural ventilation is more extensive, overwhelming the proposed (0,4-0,5) number of exchanges of air per hour. Especially in the buildings with central heating some interviewed inhabitants reported that they are having windows constantly sash.

| | | |
|---|---|---|
| Do you dry your clothes inside the apartment? | yes | 57,9% |
| How do you ventilate your apartment: a) sash window constantly open; b) wide open windows from time to time? | sash | 36,8% |
| How many times do you ventilate your home? | > 3 times | 42,1% |
| | 3 times | 26,3% |
| Does your windows stays open during the night? | no | 78,9% |

**Costs:** The majority of interviewed inhabitants consider that the costs for electricity (73,7%) and the costs for heating (68,4%) are not high. Only in the building SK that is

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with heat pumps, 56% consider the costs for electricity high. The reason could be that the flats in this building are bigger and that the bills for electricity include the costs for heating that could be ignored for a moment. The costs for heating in the buildings could be diminished for at least 30%, if the heating systems are adequately designed and balanced, as regulated.

| | | |
|---|---|---|
| Do you consider your costs for electricity as high? | no | 73,7% |
| How much do you pay for electricity montly? | < 30 euro | 36,8% |
| Do you consider your costs for heating as high? | no | 68,4% |
| How much do you pay for heating montly? | < 30 euro | 42,1% |
| Do you think that you can influence on your costs? | yes | 68,4% |

## 2.7 Recommendations

### Investors and construction companies:

- To make a balance between costs and quality, to engage design team, especially mechanical engineers, who will design according actual legislation for energy efficiency avoiding the over dimensioning of installations for heating;
- To use energy efficiency for benchmarking of their buildings;
- To engage well educated engineers and blue collar workers for increasing the quality of the construction.

### Design team

- To invest in knowledge in energy efficiency, especially in dealing with thermal bridges;
- To insist, in the design phase, usage of complementary materials (exp. facade) with good quality to avoid the problems in construction and maintenance;
- To improve design according occupants' surveys, especially to pay attention on natural lightning in the flats;
- To be encouraged in design of energy efficient sustainable buildings due to occupants' surveys from inhabitants of energy efficient buildings, representing the general satisfaction of living in such buildings and lack of serious complains;
- To take care for optimal lightning in corridors and common spaces;
- To be encouraged to design heat systems with heat pumps and exploit RES on-site;
- To be encouraged to persist in design of modern, sustainable buildings.

### Occupants

- To insist the companies responsible for delivery of heating energy to balance the central heating systems in the buildings and to avoid overheating that

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provokes more ventilation, higher consumption of energy and higher costs for heating;

- To take care of the temperatures in summer, when using air conditioners, to be over 25°C, for health reasons and considering energy consumption/costs;
- To take care for regular ventilation, but to avoid overventilation with sash windows;
- To be aware for the benefits of the regulating the temperature through thermostatic or regular radiator valves;
- To take care and be aware of the bad influence and consequences of the humidity in the air.

**Local and national authorities**

- To administrate better the documentation and enable easier approach to the documents for energy efficiency (Energy certificates and Statements for compliance);
- To find incentives and encourage investors in building energy efficient sustainable buildings;
- To take care for implementation of law regulation in design and construction of energy efficient and sustainable buildings.

## MAIN RECCOMENDATIONS

1. Investors, constructors and designers should invest in upskilling their knowledge in the field of energy efficiency, especially in decreasing the influence of thermal bridges (around windows and balcony doors, in contact of different materials in the thermal envelope and in places where geometry changes like erkers), demonstrated as feeling of movement of air (convection) while closed doors and windows. Implementing testing methods of air leakage from windows and other openings.

2. Investors and designers should focus on buildings with RES for heating and cooling, like the heat pumps and usage of solar water heaters or photovoltaic systems. That is the right way to decrease consumption of energy, increase the involvement of inhabitants, in controlling the costs for energy and personalized comfort, and decreasing the emission of $CO_2$.

3. Inhabitants should be aware of their behavior, regarding comfort and costs for energy. They should organize themselves and ask the suppliers of energy to decrease the heating period during the day, and in some circumsentes lower temperature in energy efficient buildings, that have good insulation and energy efficient windows.
4. Institutions should implement grants or other incentives for companies that are building energy efficient buildings, implementing RES and have positive POE. They

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should use POE in the new and old building under their jurisdiction and results to be utilized in their energy municipal efficient programs as relevant and reliable.

# CONCLUSIONS

General conclusion is the satisfaction of the inhabitants of the comfort. They are not complaining about costs for electricity and heating. The inhabitants in the buildings with central heating are satisfied with overheated flats and are over-ventilating, but ignoring the increase of energy consumption. The company delivering heating energy is not balancing the system according the regulation for thermal comfort. The inhabitants in the building with heat pumps have smaller temperature in winter due to taking care of the costs and regulating the regime of heating. Heat pumps and other RES should be encouraged. The temperatures in summer are lower than recommended healthy temperature. Some inhabitants cannot estimate the conditions of comfort and cannot answer all questions. Natural lightning should be improved in the flats. Acoustic comfort in evaluated buildings seems satisfactory. Natural ventilation should be controlled from the inhabitants. Thermal bridges should be better designed and minimized. Design and construction of the building should be supported with findings of Post Occupancy Evaluations. POE should be included in life circle of the buildings.

## MAIN CONCLUSIONS

1. Inhabitants are, in general, satisfied with comfort in all evaluated energy efficient buildings. POE was performed on buildings constructed from the best companies in country and the results of POE proved their quality. Two of the buildings (AS and AN) have blue collar workers certified in BEET. The score of POE, especially in thermal comfort regarding convection in the flats, is 30% better than in other two buildings, verifying their effort in skills for energy efficiency.

2. POE is method that should be popularized and implemented in future. It is especially interesting for good companies that have invested in knowledge and skills of their workers and that are interested in high quality of buildings. POE is verifying efforts in achieving comfort in living and is giving to the companies visibility from other perspective, from inhabitants perspective and can be using as marketing tools as well

3. POE is giving the microphone to the inhabitants. With POE they are having a tool to ask for better comfort of living and decreasing the costs for energy, especially in the buildings with central heating. With POE they are illuminating the products of the construction companies, the buildings, with the light of the experience from the point of view of consumer that is something new and innovative in our country.
POE is a tool for every stakeholder to achieve win-win position.

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# ANNEX I: Methodology of POE

# Post Occupancy Evaluation

# Adapted for North Macedonia

## CONTENTS

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# Tables & Figures



# Abbrevations

| | |
|---|---|
| AI | Artificial Intelligence |
| BACS | Building Automation Control Systems |
| BEMS | Building Energy Management Systems |
| BMS | Building Management System |
| EPC | Energy Performance Certificate |
| FM | Fascility Management |
| HOA | Home Owner Associations |
| HVAC | Heating Ventilation and Air Conditioning |
| MURBs | Multi-Unit Residential Buildings |
| POE | Post Occupancy Evaluation |
| TRAINEE | Toward market-based skills for sustainable energy efficient construction |

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# 1 Background

This document is developed in accordance with the activities of the project TRAINEE aiming at biger involvement of building end users in monitoing and decision making process about energy efficiency performance of the buildings. The adjusted post-occupancy methodology (POE) is a way of providing feedback about a building after occupancy. Initiatives to support POE can include the collection of energy and water performance data in-use, as well as undertaking surveys of building users to establish what is working well and what can be improved.
This document can serve you, building end user, as a tool to assist you in choosing the needs and preferences, as few or as many of the areas identified in this document.

Whether your choice is:

a) To do a basic check of your building through the Questioannarie for detection of potential causes for existing energy performance gap

b) Review your occupation approach and change behavior, or perform small investmants in order to decrease the energy performance gap and to increase the comfort, or

c) To use this toolkit for decision making process of your need to perform energy audit with deeper analisys for the causes of energy performace gap

It is preferable that the POE evaluations take place more than once over the lifetime of a building, to establish how performance changes with time. Typically, POE activities are conducted by a third party to provide an independent and unbiased view of performance.

The methodology is organized as following: Section 1 contains the relevance of POE to energy performance gap; Section 2 presents General structure of POE; Section 3 Existing tools for POE; Section 4 Proposed adjusted methodology for TRAINEE; Section 5 Draft Report Outlin for POE and lat part presents benefits to all shareholders and conclusion about implementation.

## 1.1 Defining Energy performance gap

Did you know that buildings tend to consume between 1.5 and 2.5 times the amount of energy originally predicted by their designers, according to a RIBA CIBSE database? ***The gap between the predicted and actual energy use of buildings is referred to as the 'energy performance gap'.*** Possible explanations for this gap are construction mistakes, improper adjusting of equipment, excessive simplification in simulation models and occupant behaviour. It is generally known that occupants influence residential energy consumption.

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However, only limited evidence exists for this and that's why this adjusted Post Occupancy Methodology for residential buildings is developed.

## 1.2 What is Post Occupancy Evaluation (POE)?

Post Occupancy Evaluation (POE) has its origins in Scotland and the United States and has been used in one form or another since the 1960s. Preiser and colleagues **define POE as: the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time**.
Sustainable buildings are not just about one way of construction or combining a few techniques; we have to understand the effectiveness of sustainable design strategies in relation to context, climate, scale, type of use, user, client and city. POE can reveal why a certain technique works well on one project but fails on another by surveying actual performance, any improper usage which can cancel out environmental goals, and the social and psychological effects of a building on its users. This will lead to even more successful designs with a high level of comfort. Newly built environments will therefore progressively perform better than those preceding them.
The unique aspect of Post Occupancy Evaluation is that it generates recommendations based on all stakeholder groups' experiences of subject buildings' effects on productivity and wellbeing.[1]

There is no industrial definition accepted for POE; nor is there a standardized method for conducting a POE because it focusses on the requirements of building occupants, including health, safety, functionality and efficiency, psychological comfort, aesthetic quality and satisfaction. POE is also made complex by the fact that it is evolving towards more process oriented evaluations for planning, programming and capital asset management (Federal Facilities Council 2000).

## 1.3 Relation between Energy performance gap and Post Occupancy Evaluation

The performance gap consists of multiple, frequently occurring, minor issues that occur through the **design, build and operation process.** Even this problem occurs in most of the buildings, that with this methodology we provide the user a toolkit for decision-making process for the need of deeper energy analysis. This methodology if the first step to get the answer of the question: **Do I need energy audit of the building?**
The implementation of the POE presented in this document will take **aproximatly 7 days**. This will provide you an overview of the action that you may need to take. You will be able to get an answer of the following questions:

- Do I need behavior change to lower the energy performance gap or
- Do I need a small investment or

[1] Post-occupancy evaluation - Wikipedia. https://en.wikipedia.org/wiki/Post-occupancy_evaluation

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- Do I need a help of expert that will perform an energy audit of the building?

This document is itended to be used mostly by experts and investors. The Post Occupany Evaluation methodology and approach is adapted with simplified questionnairie, which will be used in the on-line tool Knowladge HUB available on the project web site.

## 1.4 POE usage in identification of Energy Performance Gap

**The objective of POE** is to feed forward 'lesson learned' from the review of completed projects into a process that would ensure that best practices are applied in future projects. It is used to test generic and specific aspects of the planning and detailed design of buildings; as well as, test the impact of buildings on users with respect to several parameters such as: health and safety, security, indoor environment quality and functions (Zimmerman and Martin, 2001).
The POE benefits the building industry by supporting policy development as reflected in design and planning guides; and provides to the building industry with information about the building performance of buildings in use by quantifying occupant perception and physical environmental factors. POE enables the testing of new concepts to determine how well they work in occupied building and allows for identification and remedy of building problems such as uncontrolled leakages, deficient air circulation / poor circulation. POE also assists in generating information for future decision-making (Federal Facilities Council, 2000)
Post Occupancy Evaluations is used to improve the ways that buildings are used to support productivity and wellbeing and to lower the energy performance gap.
Specifically, it is used to:

- Account for building quality
- Troubleshoot building/use problems (such as change management and new work styles)
- Fine-tuning of the building services to reduce the environmental impact of the building.
- Providing a better understanding of how to operate the building that results in improved performance.
- Identifying ways of improving staff performance and motivation through improved management of their working environment.
- Highlighting areas where maintenance costs could be reduced or minimized.

## 1.5 Who can use and benefit from POE?

In the quest to understand how buildings behave, stakeholders can benefit if they think about POE as being an inseparable part of the building process. Very often, some of the stakeholders are not aware of the power that POE can play during the different stages of a life cycle of the building. Who actually can benefit from POE and how?

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a) **Occupants** should have the answer on the questions: *„Why am I paying for more energy than presented in the Certificate for energy characteristics of the building?* Why are there differences between documents/certificates and our bills? What should I do to have better comfort and to reduce the bills for energy?" They should also start asking themselves the real questions: *„Do we have environmental comfort and control over environmental conditions? Are we behaving as the architects and engineers predict it? How much it costs not to do this?* If an organization (or occupants) isn't maintaining an environment conducive to doing the work or living/staying there, what are the costs?"

b) **Architects and engineers** can learn from their practices if they check regular building behaving as intended. The evaluations can instruct better design choices, but just as often, they can offer the client worthwhile data. They can better understand occupant's behavior and use that in science for optimizing heating system, lighting or any other.

c) **Construction companies/Investors** can have significant benefit of POE as a benchmarking aid to compare across projects and over time. They can identify any gaps due to quality of design, construction, material and labor force with their skills. The results from POE applied to different buildings can be compared and will lead to understand the post occupancy building operation and the need for improvement of energy efficiency.

These are the real questions that POE will help the occupants to be answered. Together with answers obtain from the aspects we can reveal the full picture of why certain design strategies are successful or not. A mixed-methods approach, one that combines building measurements and surveys with in-person interviews and open-ended questionnaires, provide additional insights that are not always captured with surveys alone.

**The greatest benefits from POEs come when the information is made available to as wide an audience as possible, beyond the institution whose building is evaluated, to the education sector and construction industry.** Information from POEs can provide not only insights into problem resolution but also provide useful benchmark data with which other projects can be compared. This shared learning resource provides the opportunity for improving the effectiveness of building procurement where each institution has access to knowledge gained from many more building projects than it would ever complete.

*POEs encourage the client, design team and contractor to review all the building performance issues openly and holistically, allowing time for discussion and reflection. So that even if the issues raised were already known, there's encouragement to consider alternative solutions and an improved likelihood to learn from mistakes and so helping to deliver more sustainable buildings in the future*.

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This holistic approach of using POE results can demonstrate how knowledge acquired from Post-Occupancy Evaluation (POE) can be used to produce more accurate energy performance models and to lower the energy performance gap.

# 2 General structure of the POE

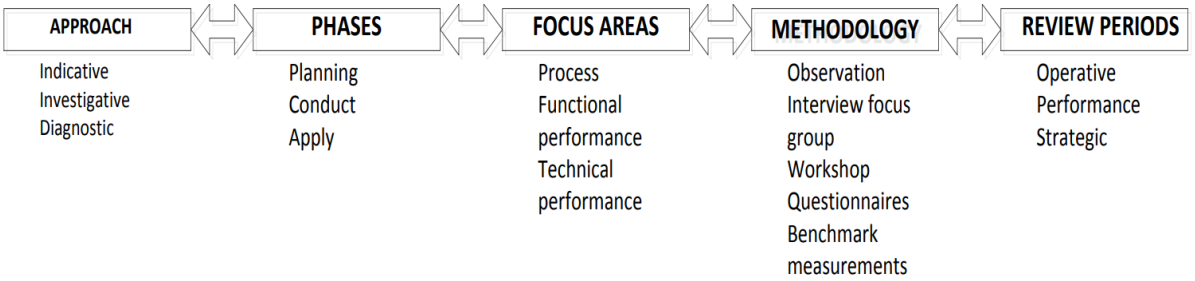


*Figure 1 General structure of POE*

## 2.1 Approach

The methods fell within the 3 POE approaches i.e. **indicative** approach (indicating of major strengths and weaknesses the building's performance), **investigative** approach (evaluating criteria in the functional program of a facility or guidelines, performance standards, and published literature) and **diagnostic** approach (correlating physical environmental measures with subjective occupant response measures).

An indicative review gives a quick snapshot of the building. It is a broad brush approach where a few interviews are combined with a walk-through of the building. A short, simple questionnaire might also be circulated. The aim is to highlight major strengths and weaknesses. The value of this is to provide useful information quickly but also to form the basis of a more in-depth study.

An investigative review is a more thorough investigation using more rigorous research techniques to produce more robust data. In this type of review representative samples of staff are given questionnaires backed up by focus group reviews and interviews to tease out more information on problems identified by the questionnaire responses.

A deeper diagnostic review is a very thorough analysis which links physical performance data to occupant responses. In this type of review, the evaluators carry out analysis of the building's environmental systems. Generally, this includes: air-handling, lighting, energy use, heating, measuring ventilation rates, temperature, lighting levels, energy use, $CO_2$ emissions and acoustic performance.

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## 2.2 Phases

### 2.2.1 Planing

The first phase Planing is to set up preliminary plan for work, budget and other resources. During this phase there are four main steps that have to be taken into consideration:

a) Purpose (initialization, scope, etc)

b) Justification (development of clear understanding of POE with all processes, information needed, client responsibilities, etc)

c) Activities (forseen activities as agreement with client, selection of level of details, identification of building structure changes, etc.)

d) Resources (availability of key eperts, building documentation, etc)

### 2.2.2 Conduct

During the second phase Conduct, the whole activities planned in the first phase are excuting. One of the main tasks in this phase is collection and analysis of data. Ensuring the quality of data during the on-site collection and monitoring of the whole process

### 2.2.3 Apply

In this third phase, findings are reported, conclusion drawn, reccomendations made. Eventually results can be reviewed, but they have to be presented in organized Report with Findings, Recommendations and Conclusion.

## 2.3 Focus Areas

### 2.3.1 Process

The Focus Area on Process provide comment evaluating the process involved in the project from its commencement to the occupation of the building. It also provides comment on any issues which hindered the project process.

### 2.3.2 Functional performance

Functional performance lists the measures to be used to evaluate whether or not each of the objectives have been achieved in the POE Report - this may be in tabular format and it is usable for providing comment regarding how the overall design of the facility addresses the functional and operational requirements.

### 2.3.3 Technical performance

Technical performance provide comment regarding how the physical systems perform under normal operating conditions (e.g. energy consumption, lighting, ventilation and acoustics etc.) vs. the design objectives/intent. This focus area evaluation provide

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comment regarding maintenance procedures and provide comment regarding defect remediation.

## 2.4 Methodology

### 2.4.1 Observation

Walk through and observation. This can use both observation, reflecting on how space is performing, and informal discussions with users to identify conflicts.

| Advantages | Disadvantages |
|---|---|
| •Few staff resources needed<br>•Can be done without any end user involvement or inconvenience<br>•Can provide quantitative data if designed appropriately<br>•Enables unbiased view | •Methodology may demand inconvenient application e.g. observations at particular times of the day<br>•Comparison can be difficult unless observer is given a methodology to apply<br>•Observation can not give accurate data |

*Target group: Building owners, Home owner association, Fascility management*

### 2.4.2 Interview of focus groups

Interviews with individuals are a useful way of getting very specific, detailed information and developing a deeper understanding of particular problems. They are best facilitated by a professional who is able to be objective. Whilst there needs to be a focus to an interview they are often most useful when conducted with a loose agenda, allowing free discussion to pick up issues that may not be initially obvious. Interviewees must be carefully selected to provide a balance of perspectives.

| Advantages | Disadvantages |
|---|---|
| • Detailed exploration of issues<br>• Fine grain of detail and insights can be generated<br>• Target very specific knowledge<br>• Easier to arrange meetings with individuals than groups | • Specific opinions do not necessarily represent broad views<br>• Biased response likely<br>• Cannot benchmark<br>• No anonymity |

There are broadly two ways of carrying out interviews. A **structured interview** where there are very specific questions or the **semi-structured interview** where there is an agenda of questions and issues, but allows the discussion to develop which may identify issues not already established.

Interviews should last no more than one hour and be preceded by a visit to the area of the building where the interviewee works making notes about any unusual features of the space which could impact on the views given. In addition, each interviewee should be given.

*Target group: Occupants*

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Focus groups are a good way of drawing out information on a range of topics. Often they are a useful adjunct to a questionnaire survey where the responses to that have identified key problem areas but you need to get more qualitative information on them to understand the problem. Focus groups are used to explore or get information on some specific building issues (exp. Building envelope, maintenance)

| Advantages | Disadvantages |
|---|---|
| •Management time needed to prepare is less than for questionnaire survey<br>•Involves relatively in few people<br>•Enables specific issues to be addressed in detail<br>•Interactions between attendees enables deeper insights<br>•Flexibility of coverage, agenda can allow issues to be explored as they are uncovered<br>•Useful for teasing out broad issues uncovered by questionnaire survey | •Expert facilitation needed<br>•Qualitative data lacks statistical rigour of survey questionnaire<br>•Bias of those who attend – therefore selection of attendees critical<br>•No anonymity – people may be reticent to say what they think |

A good focus group size is 6-8 people. Groups of this size are manageable and it enables the facilitator to get input from everyone present at the same time as getting a broad range of views.
*Target group: Occupants, Investors, People from Facility Management etc.*

### 2.4.3 Workshop

A workshop is useful for defining and **exploring broad range of problems** rather than merely discussing what those problems are. In a Post Occupancy Evaluation workshops can be a useful way to explore possible solutions to problems by using group experience. **A disadvantage is that they can be time consuming.**
A workshop should last at least half a day and have a broad agenda which identifies the focus of each session.
*Target group: Occupants, Investors, People from Facility Management etc.*

### 2.4.4 Questionnaires

It is important to consider whether a standard or tailored questionnaire is required.

a) **Standard questionnaires** offer the advantage of being able to gather consistent data across your facilities. The benefit of this is that you can benchmark buildings, or parts of buildings against each other. A standard questionnaire that is available from expert consultancies enable benchmarking a building project against others in the sector.

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| Advantages | Disadvantages |
|---|---|
| •Generates detailed quantitative data from end users<br>•Allows performance benchmarking<br>•Problems can be geographically pinpointed (i.e. where in building respondent works)<br>•Obtains a broad based opinion<br>•Anonymity can be given<br>•Enables comparative surveys to identify trends and responses to remedial action | •Requires skilled design<br>•Requires careful administration to ensure response<br>•Requires staff time to complete<br>•Requires skills to analyse and interpret responses |

b) **Tailored questionnaires** enable examination of issues specific to the building or institution. However, it is possible to combine the two approaches and use a standard questionnaire with a section that is specific to your circumstances.

### 2.4.5 Benchmark measurements

The methodology can include the assessment of seven different performance areas:

- energy efficiency;
- water use efficiency;
- indoor air quality;
- lighting and the visual environment;
- acoustics;
- thermal comfort;
- building envelope performance.

Key performants indicators that can be used to measure energy performance gap are:

1) Annual energy consumption per square meter of conditioned space (gas, electricity,
propane, diesel, fuel oil, etc.);
2) Energy use reported on an energy type basis and as aggregated total of different
energy types (heating, cooling, lightning, sanitary hot watter, ventilation);
3) Energy consumption per square meter of conditioned space, corrected for weather
conditions.
4) Normalized energy use reported on an energy type basis and as aggregated total of different energy types.
5) Disaggregated energy use by system or end use.
6) Indoor temperature

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7) Lighting levels
8) Air permeability
9) Other…

Measurement and physical monitoring e.g. light levels, noise levels, air and radiant temperatures, $CO_2$ levels, air flow rates need a level of acceptable environment to be defined for comparative purposes. Needs a clear strategy to determine measurements points, frequencies and duration of monitoring. BMS data will be invaluable provided that the BMS sensor accuracy has been checked. Can be combined with energy monitoring to assess overall building energy efficiency. Can include thermo-imaging.

| Advantages | Disadvantages |
|---|---|
| •Quantitative objective data<br>•Problems can be geographically pinpointed (i.e. where respondent works)<br>•Problems can be pinpointed in time (eg season, time of day) | •Expertise needed to take measurements and interpret results<br>•Appointment of external consultants may be needed<br>•Hiring of appropriate equipment<br>•Measurements may need to be taken over a significant period of time, therefore quick, meaningful results may be harder to obtain<br>•Measuring equipment will be left in place – possibility of disruption and inconvenience |

## 2.5 Review periods

POE addresses a number of questions:

- *Does the building perform as intended?*
- *Have the user's needs changed?*
- *What problems need to be tackled quickly?*
- *How effective was the process from inception to completion?*
- *What can be learned for future projects?*

However not all these issues can be tackled immediately on handover; some may take several months to establish. A variety of methods are used to collect this information from questionnaires, focus groups or data monitoring. In the document of Higher Education Funding Council for England (HEFCE 2006) three stages of the review process. **Operational Review,** carried out 3 - 6 months after occupation, a **Project Review** carried out 12 - 18 months after occupation, and a **Strategic Review** carried out 3 - 5 years after occupation. Once the users have got to know the building after two or three months, they can be asked in an **Operational Review** about how well it is working and whether there are any immediate problems that need resolving. The next

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feedback stage, the **Project Review**, would be carried out after at least a year of occupation when the building's systems have settled down and there has been a full seasonal cycle. This gives the opportunity to see how the building performs under a variety of conditions. It also gives users a chance to identify where the building does not meet their long term needs. The third POE stage, the **Strategic Review**, would take place several years after initial occupation when the organizational need may well have changed and the building does not now meet that.

It is very possible that after any one of these reviews or as a natural consequence of building use, changes will be made to the building. The techniques described in this guide can be used again to test whether these have had the positive effect intended.

To get the most from a POE it needs to be planned for at the outset of the project. Putting POE on the project agenda from the start will focus the minds of the project team on how the outcome of the project will be measured and it enables the team to structure and record relevant information throughout the project. Often when an evaluation is carried out after a building project, people have forgotten why decisions were made. Attendance at post occupancy evaluation sessions can be made a requirement under the consultants' and contractors' contracts, doing this will alleviate problems caused by a team member refusing to take part and/or should a project member leave the organisation so create the loss of valuable insight.

# 3 Existing POE methods

Several POE tools have been developed for the assessment of buildings. Table 1 below adopted and adapted from the Higher Education Funding Council of England (HEFCE) (2006) POE guide, summarizes suitable techniques for each review stage. This guides one in selecting an efficient technique which is useful in terms of gathering data.

*Table 1 POE Methods*

| Tool | Method | Focus | How long does it take? | Review period |
|---|---|---|---|---|
| **PROBE (Post Occupancy Review of Building Engineering)** | - Questionnaires<br>- Focus groups<br>- Visual surveys<br>- Energy assessments (energy audits)<br>- Environmental performance of Systems | - User satisfaction / occupant survey – on productivity<br>- System performance<br>- Benchmarks developed | - Process varies 2 day -2 months | - A year after occupation *(Performance review)* |
| **Building Use Studies(BUS)** | - Walk through of buildings<br>- Questionnaires<br>- Focus groups | - Occupant satisfaction<br>- Productivity | 10-15 minutes to complete questionnaire | A year after occupation*(Performance review)* |

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| Tool | Method | Focus | How long does it take? | Review period |
|---|---|---|---|---|
| **Design quality indicators** | Questionnaires (online) | -Functional performance<br>- Building quality<br>- Impact | 20-30 minutes | At design stage & after completion (*Operative / Performance review*) |
| **De Montfort method** | - Forum<br>- Walk-through of buildings | - Process Review<br>- Functional performance | 1 day | A year after occupation (*Performance review*) |
| **Energy Assessment & reporting methodology** | - Energy use survey<br>- Data collection (energy bills) | - Energy use<br>- Potential savings | 1 week /1 person | Anytime / A year after occupation (Operative / Performance / |
| **American Society for testing and material (ASTM) ASTM Standards for Whole Building Functionality and** | - 2 matching Questionnaires (Multiple-choice) | - Functional performance (Occupants requirements)<br>- Technical<br>- performance (Serviceability of buildings) | Process varies | Anytime / A year after occupation (*Operative / Performance / Strategic Review*) |
| **Serviceability Tools & Methods (ST&M)** | Questionnaires | - User / stakeholder satisfaction, perception of quality<br>- Functional<br>- performance<br>- Design requirements<br>- Process<br>- Technical performance | Process varies | Anytime / A year after occupation (*Operative / Performance / Strategic Review*) |

There is a danger of gathering many data that may be valuable but leaves a significant data-handling problem, which at the end may not be analyzed because of the magnitude of the task. The usefulness of the technique is based on a balance of useful information gathered for the effort required. When deciding which techniques to use it is helpful to consider how different techniques can be combined.

For example, combining a questionnaire with a focus group or workshop will enable different levels of information to be gathered with the workshop or group being used to tease out some of the results from the questionnaire. It is important to make the study manageable by erring on the side of gathering less data, but focusing on the quality of it. So rather, than use every technique for each area of the review select those that will best meet your purpose.

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# 4 Proposed methodology for the project

TRAINEE project will use a structured review of the process of delivering a project Post-occupancy evaluation (POE). Following POE tools and methods will be utilized:

*Table 2 Proposed methodology for TRAINEE*

| Tools | Methods | Time |
|---|---|---|
| 1) PROBE (Post Occupancy Review of Building Engineering)<br>2) Building Use Studies(BUS)<br>3) Energy Assessment & reporting methodology | - Questionnaires<br>- Focus groups<br>- Visual surveys<br>- Walk through of buildings<br>- Data collection (energy bills) | 7 days / POE |

As baseline benchmark it will be used the Energy Performance Certificate (EPC) issued by the licensed company for performing energy audits.

- **This system of Post Occupancy Evaluation will be based on the following activities:**

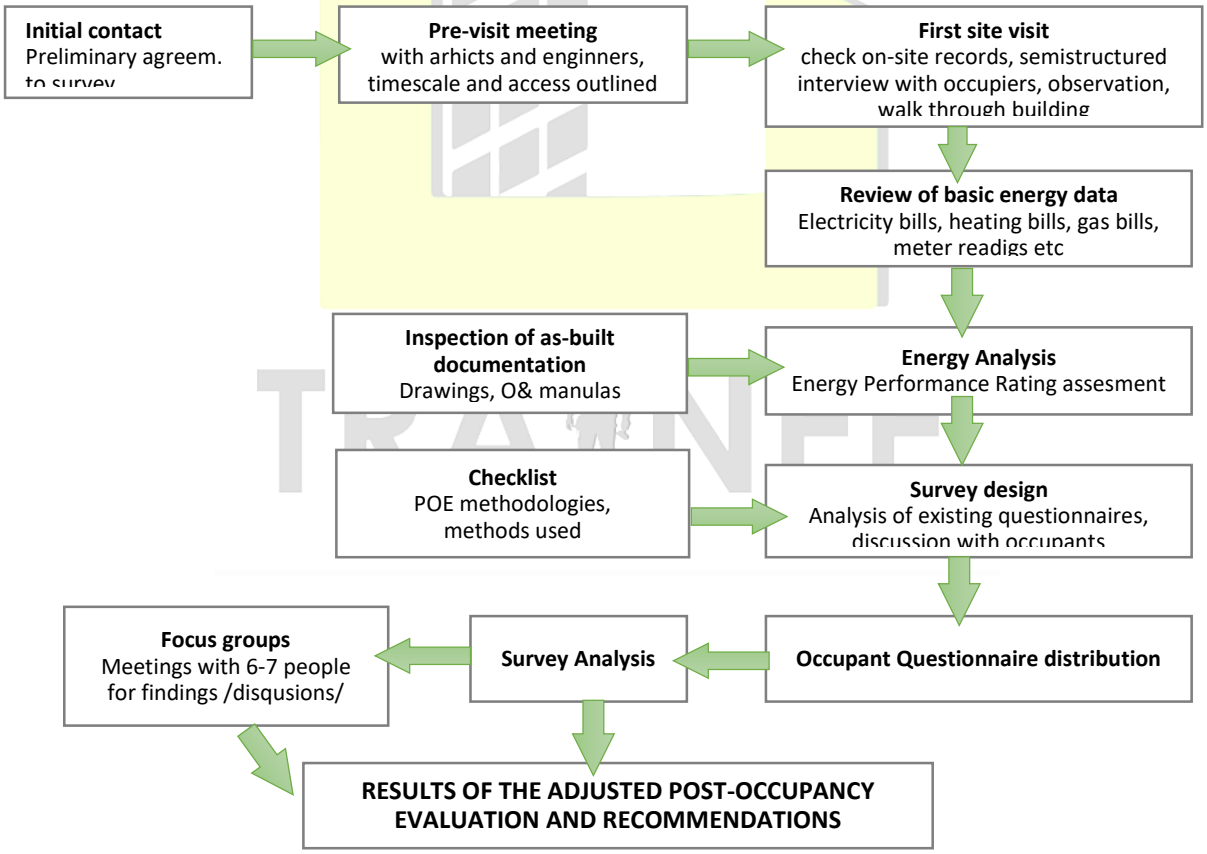


*Figure 2 Activities in Posto Occupancy Evaluation*

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## 4.1 Contact and pre-visit meeting

Communication with HOA (Homeowner association) or President of the house council should be done on the very beginning and maintain during the whole process. If possible, request a dedicated person that will provide data information for the needs of POE.

## 4.2 Visual surveys (Walk through building, site visit)

This approach employs a team of experts to visit the facility and assess its performance by observation. If the team is well selected, a significant amount of information can be gleaned simply by observation. Some amazingly powerful indicators include: covering 'observation' windows, corridors used for storage purposes, windows propped open for ventilation, broken door hardware, improporer usage of lighting, damage insulation, offices or spaces accommodating more than their designed capacity, etc. Construction detail issues can include leaking roofs, overflowing gutters, cracking brickwork, excessive heat gain, defective door hardware, leaking taps etc.
The importance of the aspect under consideration, the time available, the cost and availability of the target groups will determine the choice of the data collection instrument/s. Target groups may include facility managers, facility staff and members of the community.
During this process **small groups of users are interviewed** which provides the prompt for their comments and observations.
Visual inspection of 11 topics fall into three main groups:

- **Passive measures**: envelope, structure, window design and advanced natural ventilation.
- **Mechanical services**: heating, cooling, sanitary hot water, ventilaton and air-conditioning.
- **Electrical and controls**: lighting; controls and operation, and ICT - information and communications technology.

Findings from the visual inspection will be used in preparing the Focus Groups agenda.

## 4.3 Collection and review of basic energy data

Permission to capture data from homes will have to be agreed with occupants and will be subject to data protection regulations, which includes; informing that their personal data is being processed, clearly stating the purpose of using this data and their personal information, and an instruction on how they can subsequently opt-out. The intention is that this data will be used to support continual improvement and ensure buildings are complying with requirements. Personal data must be safeguarded by

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developers and only shared with the resident or tenant who generated the data unless agreement to share data more widely is explicitly given by the resident.

The process of data collection includes informations about physical facilities, comfort and records regarding consumption of energy. The methodology includes the assessment of seven different performance areas:

- energy efficiency of HVAC,
- water use efficiency,
- indoor air quality,
- lighting and the visual environment,
- acoustics,
- thermal comfort,
- building envelope performance.

Indicators, in relation to the energy efficiency, that could show reduction of energy consumption and costs, in the use of resources and ultimately, in decreased environmental damage, are:

- Annual energy consumption per square meter of conditioned space according energy origin (gas, electricity, propane, diesel, fuel oil, etc.);
- Energy use reported on an energy type basis and as aggregated total of different energy types according usage (heating, cooling, ventilation, sanitary watter, lighting.);
- Energy consumption per square meter of conditioned space for heating (nominal demand);
- On-site renewable energy generation;
- Sound level;
- Thermal imaging;
- Lighting level;

## 4.4 Survey design and analysis

### Questionnaires for the occupants

This information will be used to assess areas that need improvement, provide feedback for similar buildings and projects. Responses are anonymous.

*Table 3 Questions for the occupants*

| | |
|---|---|
| 1) How much time you stay in the building (Hours >1 1-2 3-4 5-6 7-8 >8)<br>2) Does the quality of the air have a negative effect on your work/living performance?<br>3) Do you feel the air fresh or stale?<br>4) Do you feel the air humid or dry?<br>5) Do you feel air movement?<br>6) Do you have control over ventilation?<br>7) What is the indoor temperature (per room if possible)? | 8) Does the temperature have a negative effect on your work/living performance?<br>9) Is the temperature in winter too high or too low?<br>10) Is the temperature during the summer too high or too low?<br>11) Does the distraction from noise have a negative effect on your work/living performance?<br>12) Is there significant distraction from noise outside the space?<br>13) Is there significant distraction from background noise? |

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14) What is the light level in the comman areas, coridors etc. (low, medium, high)?
15) Does the quality of light in this part of the building have a negative effect on your work performance? (commercial building only)
16) Is there too much or too little natural light?
17) Are you using blinds/shutters for effective control of natural light?
18) Do you dry your clothes inside the apartment?
19) How do you ventilate your apartment: a) sash window constantly open; b) wide open windows from time to time?

20) How many times do you ventilate your home?
21) Does your windows stays open during the night?
22) What is the air temperature in summer when cooling system is ON?
23) How many hours per day your cooling system is ON during the summer time?
24) Do you consider your costs for electricity as high?
25) Do you consider your costs for heating as high?
26) Do you think that you can influence on your costs?
27) Do you think that you can influence on your comfort?

The POE needs a level of acceptable environment to be defined for comparative purposes and allows you to evaluate the performance of different components and aspects of a building, including:

- building fabric
- building services and controls strategies
- energy, fuel and water use
- handover and commissioning processes
- occupant satisfaction
- occupant comfort

| Selected POE indicator | Data collection method | Key stakeholders for data collection |
|---|---|---|
| (0) Building fabric | Survey / Questionaries' / Commissioning Process Documentation | Project team / Designers and Facilities Management (FM) Personnel |
| (1, 2, 3) Building electricity, water, gas consumption…. | Metering/Billing Data (Monthly/Half yearly/Yearly) | Occupants/Tenants/Owners, Designers and Facilities Management (FM) Personnel |
| (4) On-site renewable energy generation | Metering/Billing Data (Monthly/Half yearly/Yearly) | |
| (5) Building systems commissioning | Commissioning Process Documentation | Designers/Construction company/ Facilities Management (FM) Personnel |
| (6) Monitoring of indoor air temperature and humidity | Readings or Actual Measurements, | Occupants interviews / Facilities Management (FM) Personnel |
| (9) Routine preventative maintenance program for HVAC systems and building enclosure (if any) | Process Documentation | Occupants interviews / Facilities Management (FM) Personnel |

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| | | |
|---|---|---|
| (11) Use of building automation control systems (BACS), Building Energy Management Systems (BEMS), and Artificial Intelligence (AI) to reduce energy consumption (if any) | Survey of facilities, Management and BACS, BEMS, and AI System Manipulation Experiments. (Quantitative and Qualitative) | Facilities Management (FM) Personnel |

Particular POE Indicators requiring qualitative data collection methods, as shown on the table below. **Indicators 7, 8 and 10**, may be collected from occupants, through incentivized **online surveys** and **focus group interviews**. Depending on the feedback if problem areas are identified, further research may be warranted to fix problems.
Occupant feedback often highlights areas of concern FM and residential life personnel are not aware of (i.e. dissatisfaction with level of control over temperature, frustration with low flow fixtures, and efforts to circumvent sustainability features).
User surveys can provide insight about design features, highlighting what should be implemented to maximize sustainable behaviors in practice and what should be avoided in future designs.

| Selected POE indicator | Data collection method | Key stakeholders for data collection |
|---|---|---|
| (7) Occupant satisfaction with the controllability of systems-temperature and humidity | Survey-open ended questions, yes/no questions and 7-point Likert attitude scale questions. | Designers and Occupants |
| (8) Building controls ease of use (lighting switches, thermostat etc.…) | Survey-open ended questions, yes/no questions and 7-point Likert attitude scale questions. | Designers, Occupants, and FM Personnel |
| (10) End-user consumption awareness | Documentation of educational methods employed | Occupants |

## 4.5 Focus groups

One of the best techniques in POE to collect information is through focus group. This adjusted methodology divides its focus groups to 3 divisions: **a) Occupants; b) Home owner association / Facilities Management**; **c) Investor / Construction company**
The group of people who attend this meeting is limited consequently; it is more manageable than other parts of study. For groups "a" and "c" people and supervisors who are in charge of these sections are recognized and limited, hence meeting with these people as focus groups changing to an interview. Interviewing these people is really valuable because they are professionals in charge and information gathered in this method is being collected directly from these people. On the other hands, supervisors are identified, therefore they are more cautious in order to provide feedback and if they don't feel safe their answer might affect the study and make it

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unreliable. Thus, it is always better to provide them with agenda and questions in advance. The other advantage of this action is people who are attending the meeting are already prepared so it is more probable to receive all the necessary answers.

# 5 Proposed Draft Report Outline for POE

**1. Project Summary**

**2. Delivery, Operational, Business and Functional Performance Review**

- Process (Brief, Design, Construction, Commissioning, Occupation);
- Functional Performance (Strategic value, Aesthetics and Image, Space, Comfort, Operational cost);
- Technical Performance (Envelope, Physical systems, Environmental systems, Adaptability, Durability);

*2.1 Project Team*

- List of project team members performing POE have to include energy auditors with following professions: *architect, construction engineer and MEP engineers*;

*2.2 Users*

- A questionnaire and a follow up focus groups / interview for users to assess building performance, the outcome will be a series of recommendations;

*2.3 Investor/Building company*

- A questionnaire and a follow up workshop / interview for the client to assess project delivery, operational and functional performance. The client will be asked to provide details on how the project has met the expectations outlined in the business case; The outcome will be a series of recommendations;

*2.4 Review of collected Building Performance Data*

- Actual data is to be collected on building performance and compared to industry best practice so an assessment can be made on the buildings energy performance;
- Equipment/methods used during the data collection;

**3. Summary of Recommendations**

- A tabulated summary of the recommendations;

**4. Conclusion**

# 6 Overview of POE benefits to all stakeholders

Potential POE benefits include discoveries that can improve a building's performance over time, avoid repeated errors by the design team, and encourage better communication among owners, facility managers, and occupants.

The purpose of this section is to **present benefits to stakeholders** so they could think about the POE as being an inseparable part of the building process. Very often stakeholders don't even realize the power which the POE can play during different stages of a life cycle of the building. Performance evaluation of new or retrofitted

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buildings can serve to show whether promised benefits are actually delivered, potentially speeding their adoption by industry.

The benefits below are explained by stakeholder group:

**Investors and construction companies**

**POE provides informations for investors and construction companies regarding:**

- How well a building is working related to the original design intents?
- How it compares to similar buildings or established benchmarks?
- How a building can be improved;
- Realization what are the gaps in design/construction that have impact on utilization;
- Get inspired to acchieve better quality of future perfrmance;
- Get courious for implementation of new technologies, so they can offer new and better services;
- Opportunity for improving the effectiveness of building procurement (access to knowledge gained from many more building projects than any institution would ever
  complete).
- Getting insights into problem resolution in balancing costs and quality.

**Design team**

Design teams depend on available financing and often are in a conflict of ideas versus financial constrains although sometimes a verification of the performance proves to be useful for the future designs (and marketing).

**POE offers:**

- Improvements to space utilization based on occupants' surveys;
- Responding to user needs;
- Built-in capacity for potential building adaptation to occupants' changes and growth;
- Ideas for implementation of new materials, technologies and approaches in design of energy efficiant and sustainable buildings;
- Different uses for Multi-Unit Residential Buildings (MURBs) components through flexible design.

**Occupants**

Occupants are end –users, theoretically the most important ones in a chain. POE can be useful tool for the occupants to achieve:

- Control of the the indoor environment
- Knowledge how to reduce consumption and costs for energy (heating, cooling, lightning)
- Knowledge how to acchieve positive health and wellbeing impacts
- Thermal comfort
- Daylighting and visual comfort

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- Low level of noise
- Optimization of services to suit occupants,
- validation of occupants' real needs,
- reduced ownership/operational expenses,
- Improved competitive advantage in the marketplace.

**Local and national authorities**

Local authorities and national institutions as Energy Agency, or other non-governmental interest groups should consider the creation of a publicly available POE database where designers, builders' and occupants' experiences about a building's performance could be deposited. As more items are stored and as it grows over time, facilities managers may use information from such a POE depository to make strategic decisions in a proactive manner, rather than using the information derived from a POE to undertake retrofitting and renovations.
Energy performance certificates (EPC) can be compared over time with POE reports that can help in early detection of energy performance gap.

"If we don't understand outcomes better and meet expectations more reliably, we might not have much of a business in a few years' time", Bordass and Leahman.

## Next steps

1) The POE methodology will be applied by the project team on four buildings: two buildings constructed by companies with certified workers for implementation of energy efficiency measures participated in the previouse project BEET, and other two buildings constructed by companies whose workers have no record for skills to proper implement energy efficient measures. The report will be published and aobtained results will be promoted on the conference with representatives from all relavnt shareholders.

2) In parallel the project will provide implementation of the methodology though online platform (Knowladge Hub) as the occupants (building end users) can use for self-aassessment of energy performance gap of its building. The Knowladge Hub will be rich with advices for the home owners and builders how to lower the energy performance gap.

3) The support for online platform will be provided by the Knowledge Center team where project final results will be fully available in order to provide sustainability of TRAINEE results after project end.

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# Annex 2 Piloting BIM software through case study to assess the energy performance gap

## 1.1. Project description

The strongest promotional impact will be the demonstration of benefits of using of BIM tools, as the certified professionals for BIM will be engaged in piloting the use of BIM software in order to express the potential of BIM for reduction of two gaps: first one between the energy performance of new building as projected and after construction and second one between designed and actual energy performance of the building.

First gap is demonstrated with comparison of architecture design and actual constructed building through analysis of construction materials, the chosen products, the systems used and EE-Energy Efficiency solutions executed, which will make the difference in building quality visible for construction companies and consumers.

The training done during more than 110h to several professionals and companies introducing the use of Edificius by ACCA plus Solarius permitted to understand this approach.

Second gap was demonstrated with comparison between performance indicators during architecture design and energy consumption. Something that could be useful for next programmes is a follow up from the very beginning of the developing process with one developer till the final delivery of the building and monitoring during two years its consume. Probably, after revising the work done during this programme it would be still more interesting to have to equal buildings where one of them has been planned, designed and built under traditional premises and another that has been developed under BIM and EE premises. The difficulty to have two equal buildings and a developer opened to that process makes the perfect need for a next EU programme that could help and push to spread these processes.

TRAINEE has counted with the help of Delta Projekt for developing a similar process and the preparation of two case studies is presented below.

It is important to fix the concepts that helps to a better energy consumption through all phases in the building life cycle.

The first one is how urban planning can help to get profit of suitable orientation, less shadowing (own one or neighbor buildings projected one) and urban regulations that can help on that (number of glass openings, possibility to create balconies, terraces, flat roofs…). When urban planning is fixed, the design process cannot vary these conditions and these conditions could be easily checked through e-permit evaluation.

This concept called "Intelligent Communities Lifecycle", in the case of Macedonia is extremely useful as one of the biggest energy consume is based in public heating combined with private heating too.

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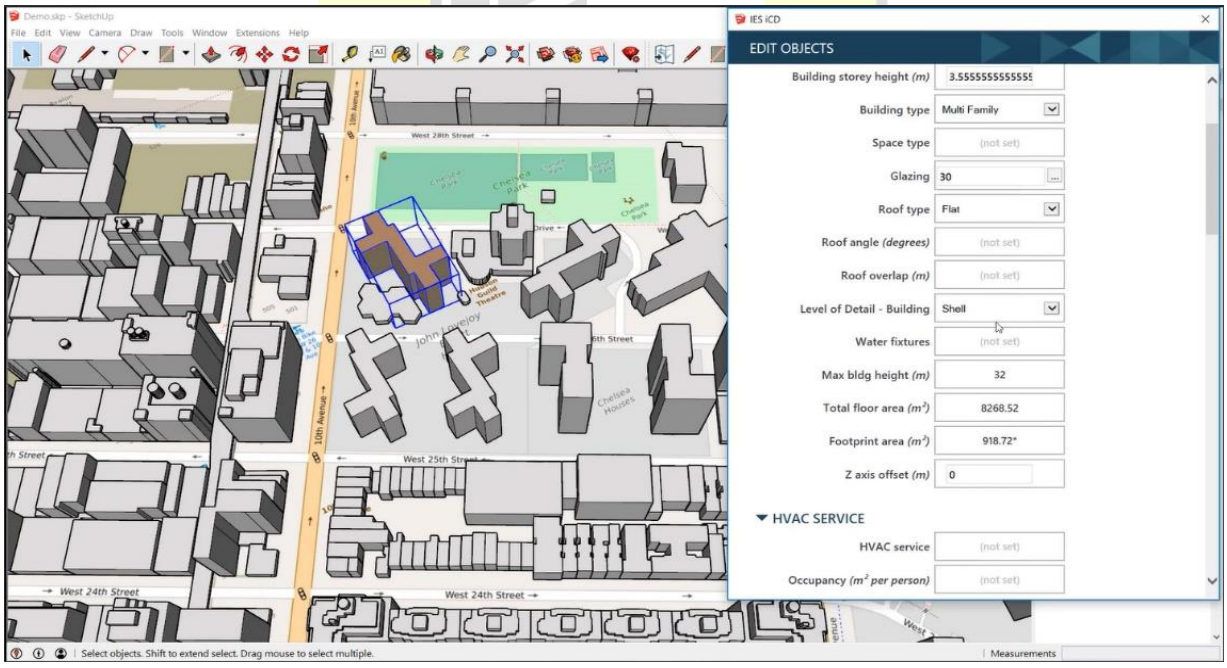
This "energy public consume" makes difficult an exact bill for apartment and for housing block so a measure taken in this sense will be impossible to track per single use. The approach will have to change to developing sustainable communities through performance analysis solutions. This would have to be converted into individual buildings analysis that could permit to have a counter per building instead per user, allowing new buildings as well as retrofits to be designed to consume significantly less energy without sacrificing occupant comfort. Larger groups of buildings as campuses and neighborhoods will apply better these energy design concepts to entire communities and not just individual flats or buildings.

TRAINEE has focused in the PV energy modelling proposal and probably could have a second part for monitoring and analysis and how they can be integrated into a digital twin and a digital twin for sustainable design.

This approach will be more and more important as we need to get Sustainable Development goals settled by UN in 2015, Net-Zero Buildings by 2050 in UK and Europe, AIA 2030 Commitment in US, etcetera. In most cases, the communities that need to be reconfigured with PV solar systems to reduce their energy consumption already exists rather than being created from sketch. TRAINEE has been focused in both fields: the one to retrofit existing buildings with solar systems and the one to help architects and engineers to simulate energy gains and losses in new buildings.

**Phase 1** is based in selecting the housing block




or the new design of a single house

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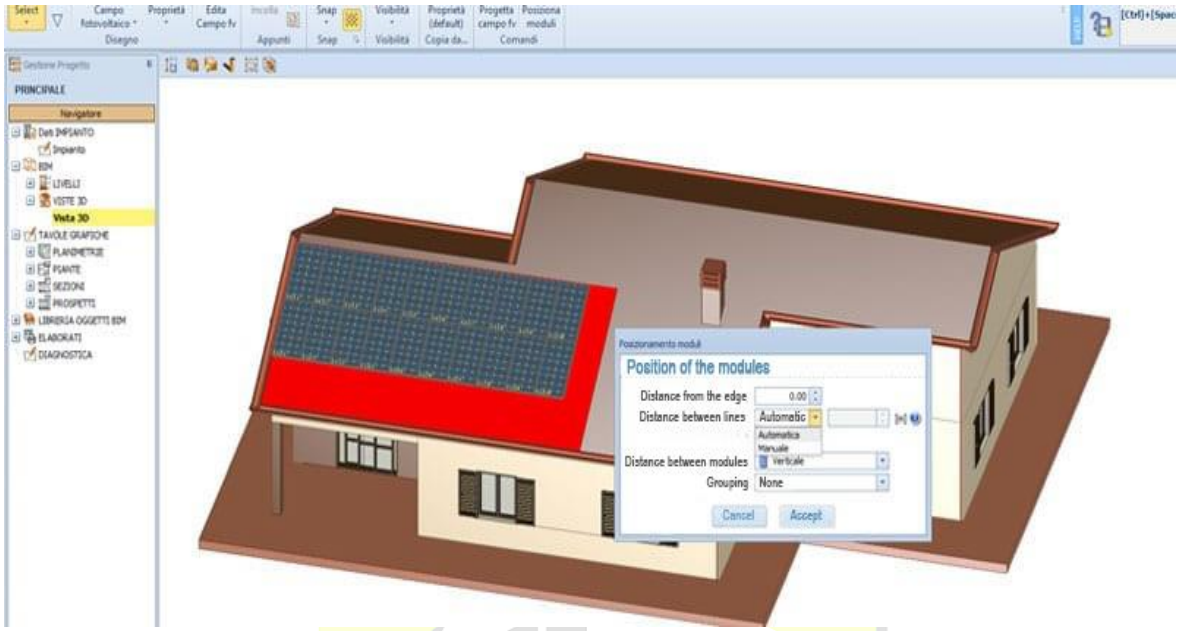
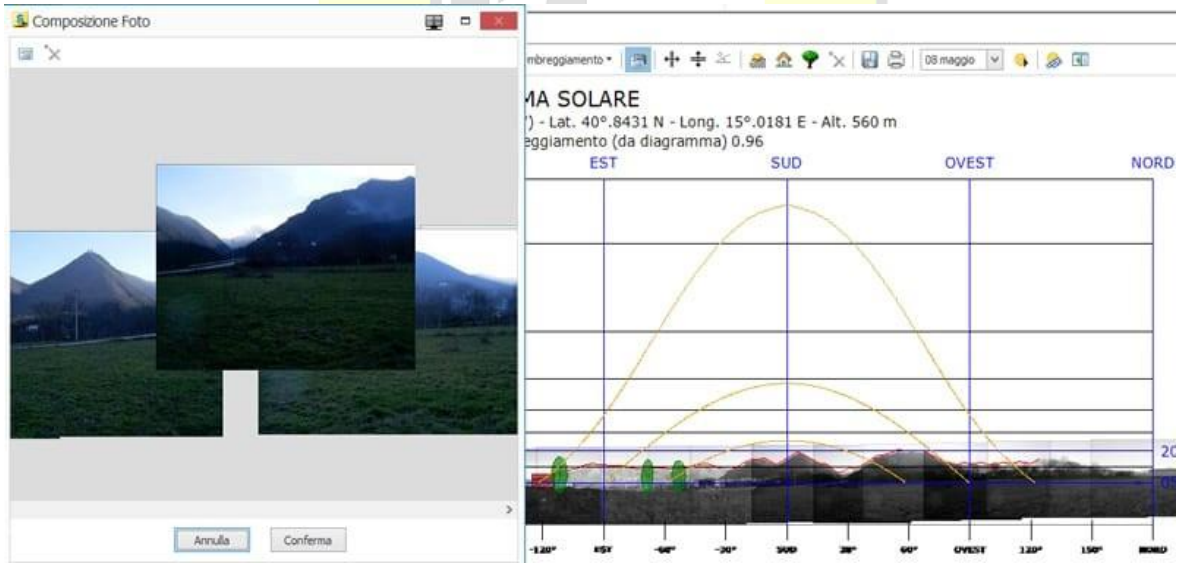



**Phase 2**, commented before, takes into account the existing conditions of the physical context (latitude, weather, solar orientation, existence of rivers, mountains and neighbor buildings)




**Phase 3** is based in the calculation of solar irradiation from climatic data from Meteonorm, PVGIS or Macedonian Geologic Institute. In TRAINEE programme, Solarius PV by ACCA has been used to estimate the photovoltaic solar production from real data of the solar irradiation available acquired from the main reference climate databases

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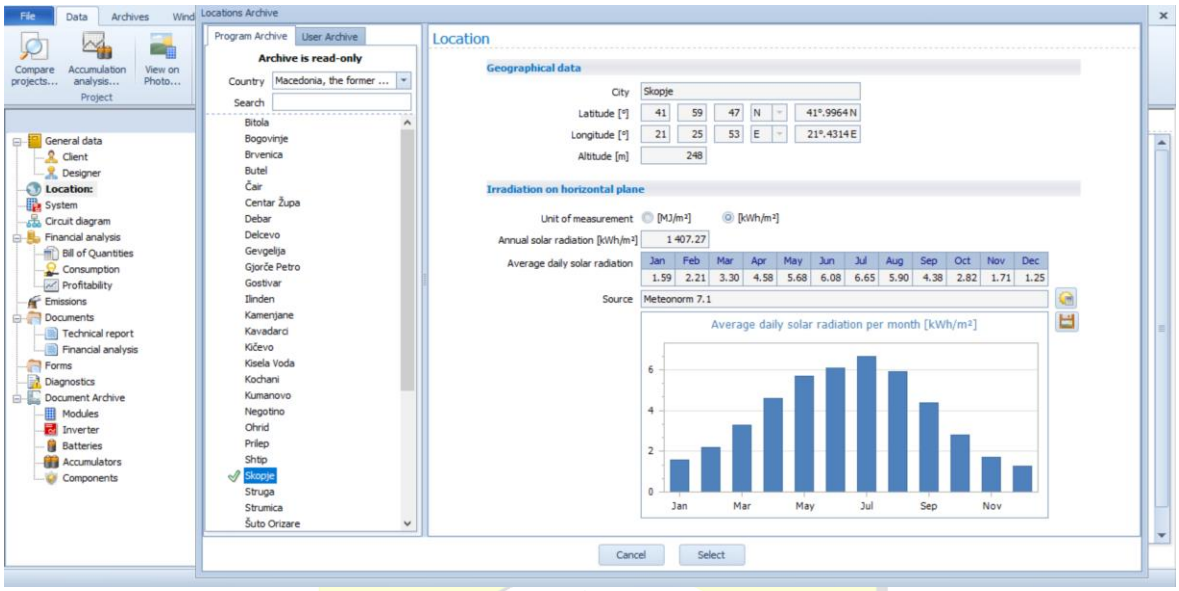
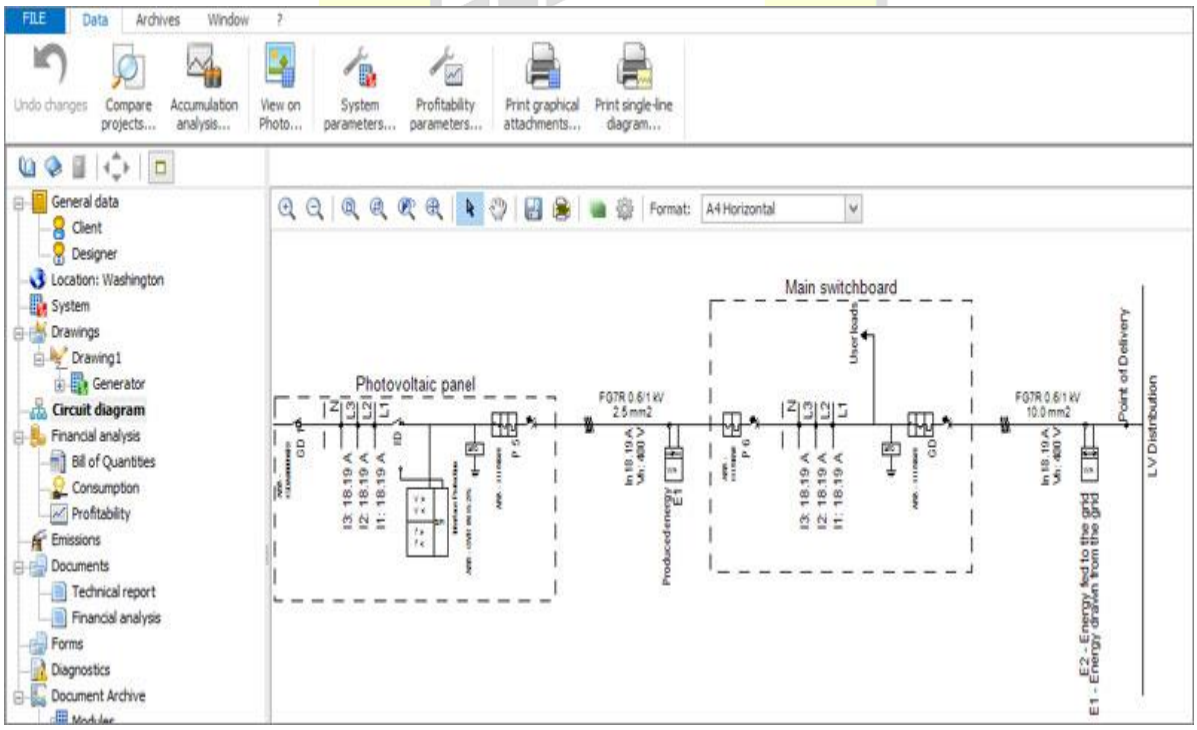



**Phase 4** configures the automated drawing of the single-line electrical diagram of the photovoltaic installations, having the option of customizing it with the addition of electrical panels (in AC and DC), electrical protections on the output or input, types of cables, etc. This single-line electrical diagram of the photovoltaic installation is represented in a complete plan with general data, legends of graphic symbols with details of the types of components used and is ready for printing or export in PDF, DXF, DWG, etc. formats.



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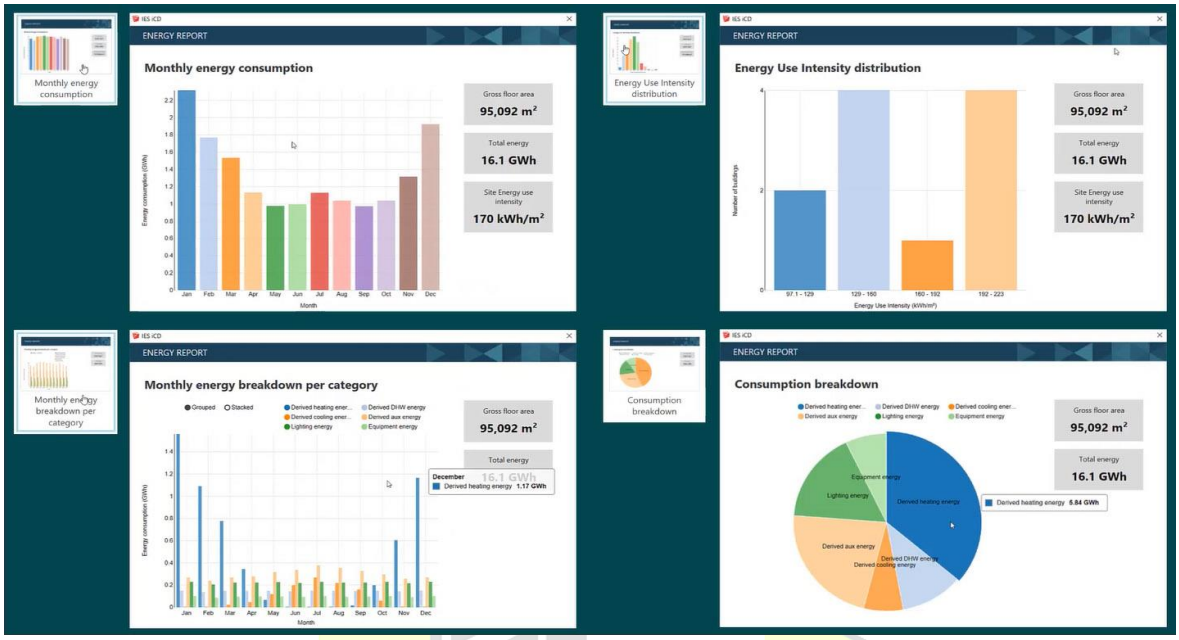
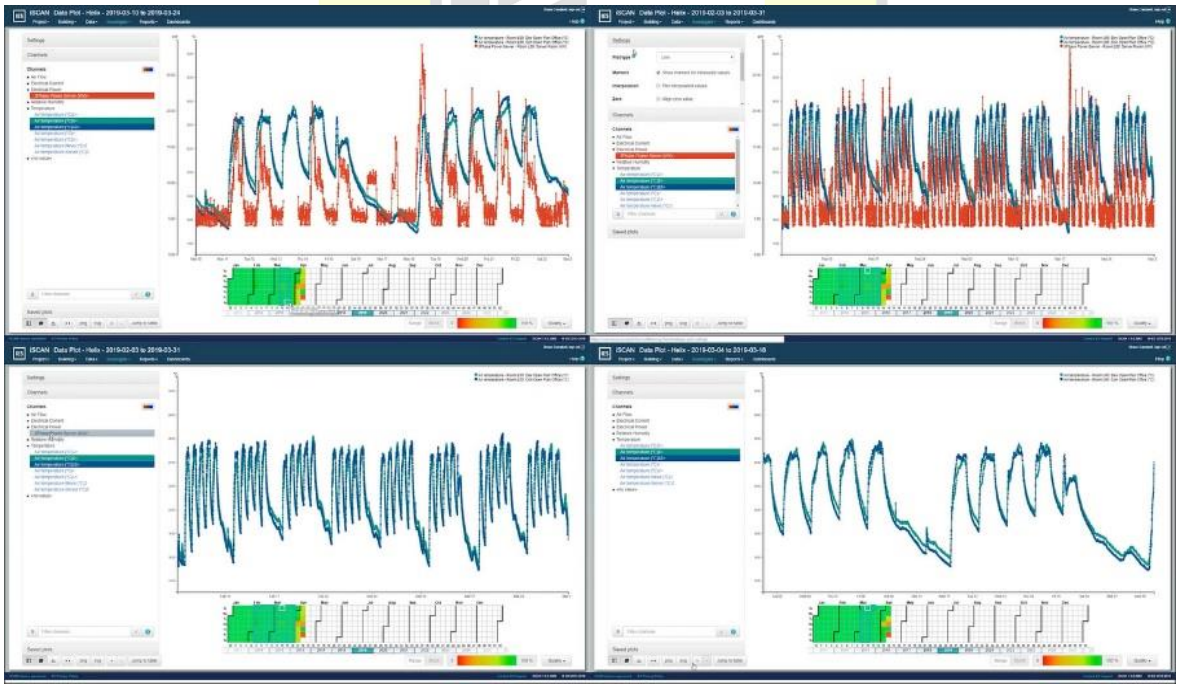
**Phase 5** explores the tracking of consumption divided according to months of the year. Secondpart of the graphic the distribution of the energy consumption is described as per its purpose (i.e heating and cooling, lighting, hot water, electric devises etsc)




**Phase 6** fixes the energy savings (first image) and money flow control (second image)



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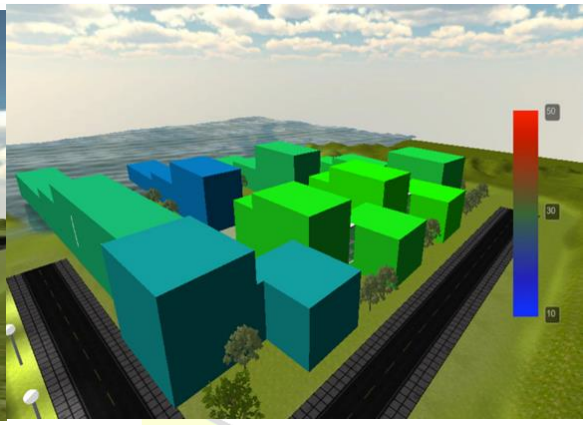
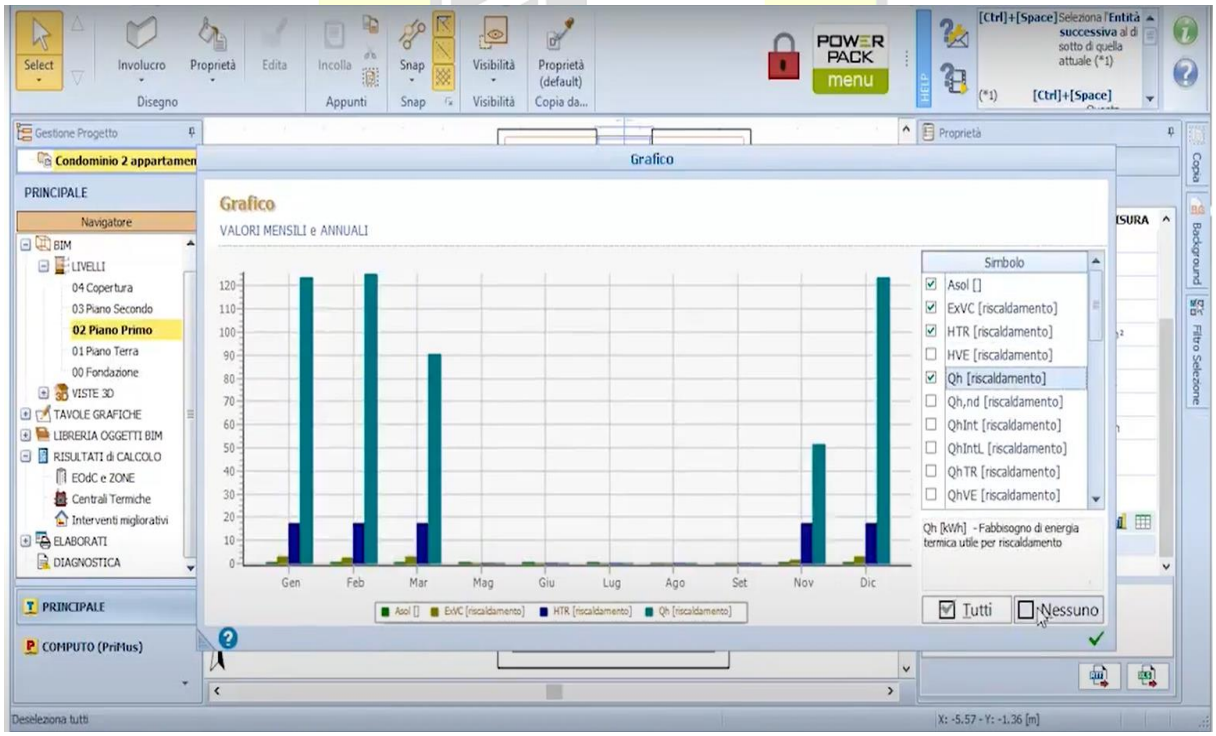
# Case Studies

## 2.1 Block Housing in Skopje, Macedonia

Creation of an optimized model integrated with BIM

Utilization of combination of tools, for example usage of TerMus BIM for simulation of energy performance of the building. Simulation based on build materijals. Location and weather condition can provide needed energy for AIR conditioning  per months.





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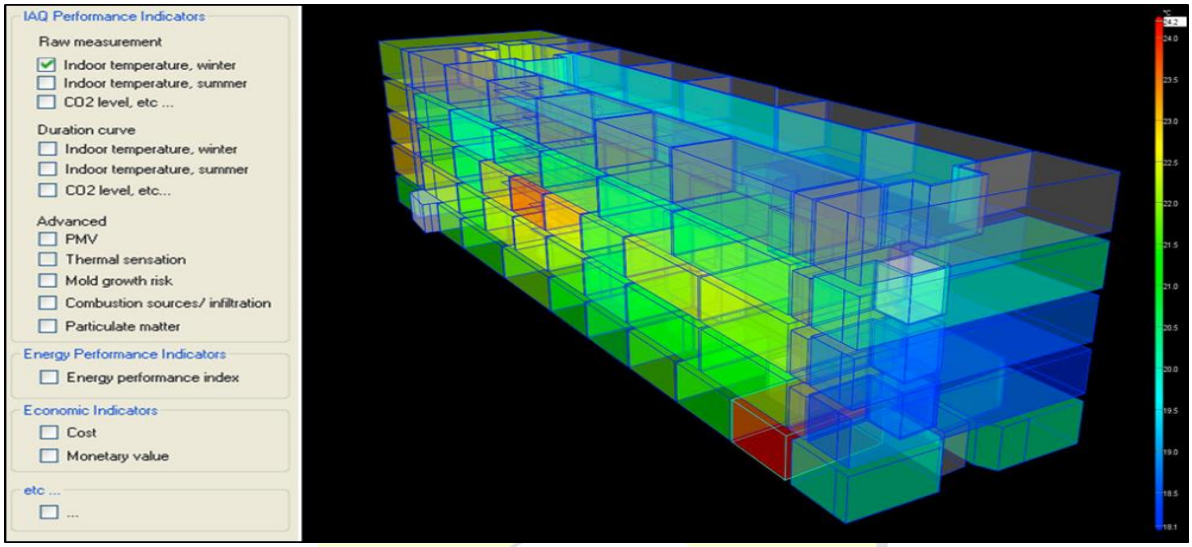



IFC provides an environment of interoperability among IFC-compliant software applications in the architecture, engineering, construction and facilities management (AEC/FM) industry

The assessment levels were comprised as optimization stages:

BIM model (IFC/ACCA + Edificius)

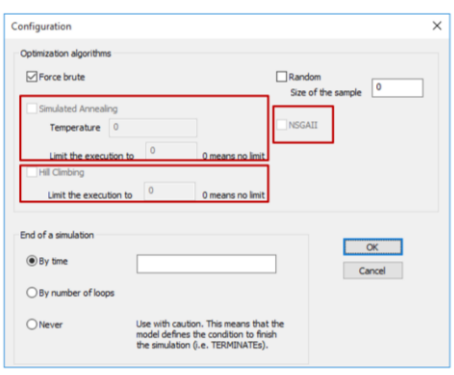
https://www.accasoftware.com/en/thermal-bridge-software

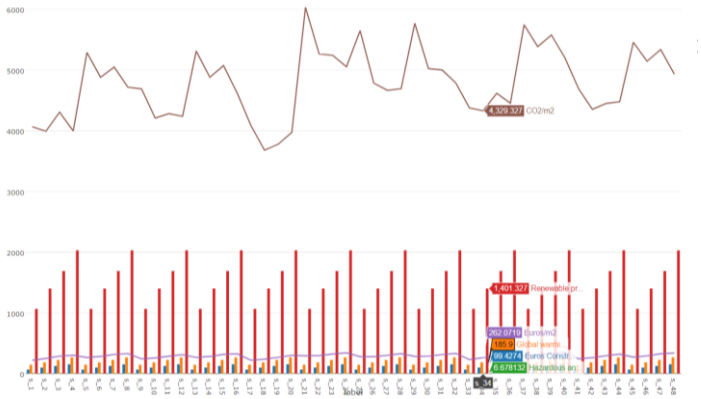
Energy model (Solarius)

Optimization software Multi objective building optimization

## 2.2 Single House in Skopje, Macedonia

Simulation model to find the best comfort, energy and cost scenarios for building refurbishment.



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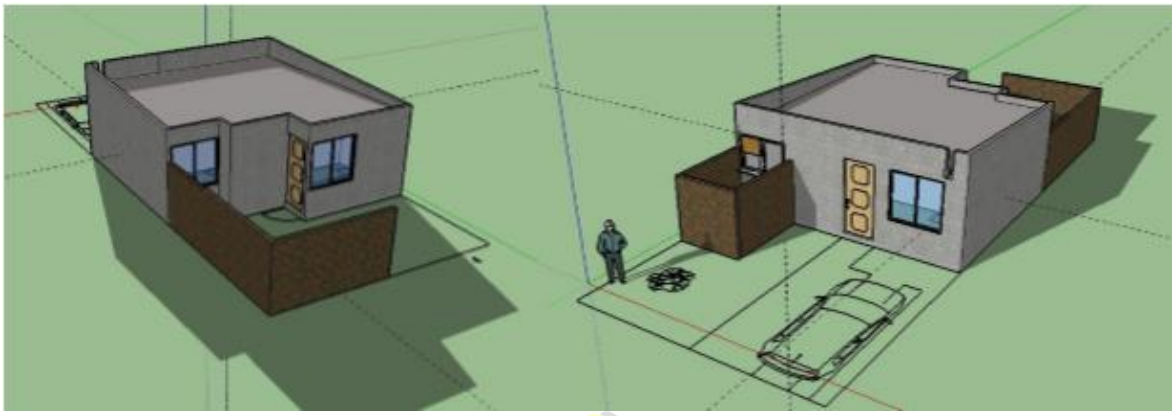

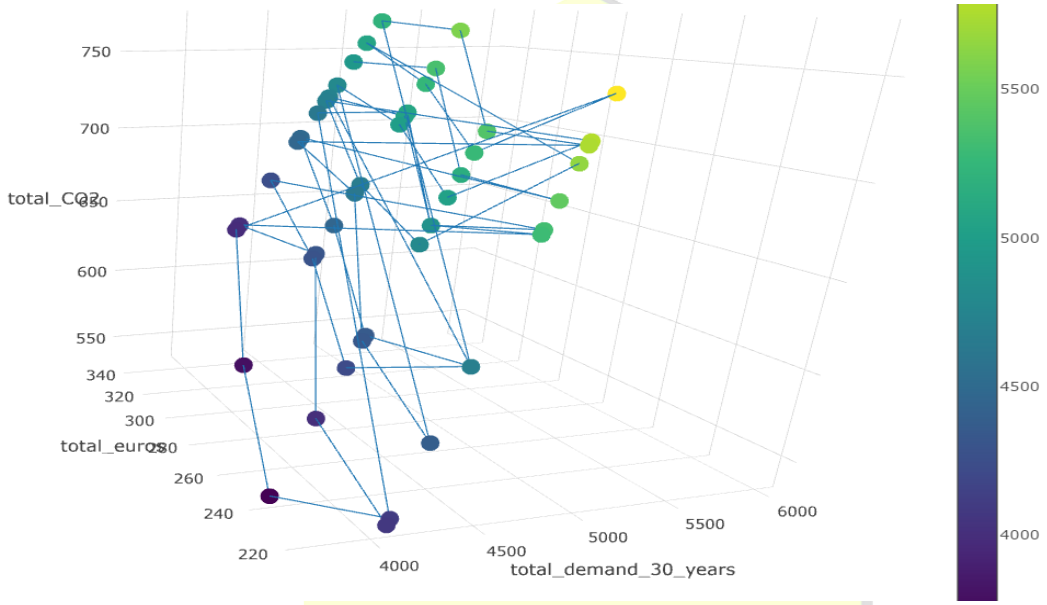


The experiment is simulated at a passive level taking into account vernacular strategies of the SouthEast regions, such as natural ventilation and the use of sun protection (comfort-economic).

The model is used to find the optimum with active systems, applying cost-optimal criteria of energy and economic efficiency.

**The conclusion about the evaluation of buidlings** is that upskiiling workers and usage of BIM, especially for simulation of thermal bridges, has provided to build with lower gaps in energy performance of buildings.