Project no.:	**893945**
Project full title:	**Energy flexible DYnamic building CErtification**
Project Acronym:	**E-DYCE**

Deliverable number:	**5.1**
Deliverable title:	**Case study monitoring report**
Work package:	WP5
Due date of deliverable:	M24
Actual submission date:	M24 - 31/08/2022
Start date of project:	01/09/2020
Duration:	36 months
Reviewer(s):	Michele Zinzi, ENEA
Author/editor:	Michal Pomianowski, AAU
Contributing partners:	POLITO, EMTECH, ESTIA, ENEA, NEOGRID

Dissemination level of this deliverable	**PU**
Nature of deliverable	R

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 893945. Any results of this project reflects only this consortium's view and the European Commission is not responsible for any use that may be made of the information it contains.
Further information is available at www.E-DYCE.eu.

Document history

Ver. no.	Date	Authors	Changes
0.1	14/03/2022	Michal Pomianowski	First draft of table of content circulated to the consortium partners.
0.2	21/03/2022	Michal Pomianowski	Preparation of version to be presented and discussed by all partners at the E-DYCE consortium meeting in Athens.
0.3	08/07/2022	Michal Pomianowski	Begin integration of Danish case studies integration.
0.4	01/08/2022	Michal Pomianowski Olena K. Larsen Pierre Vogler-Finck Giacomo Chiesa Vassilis Georgoutsos	Integration of Torre Pellice (Italy) case studies, Section 4. Further integration of Danish Case studies. Integration of section regarding pilots integration in real time data architecture (FusiX), Section 10.
0.5	11/08/2022	Michal Pomianowski Belias Evangelos Tristan de Kerchove	Integration of Geneva (Switzerland) case studies, Section 3. Editing number figures and tables numbering.
0.6	15/08/2022	Michal Pomianowski	Final editing chapters numbering/style, text, figures, tables etc. Sending report for internal review without Section 6 and 7.
0.7	22/08/2022	Michal Pomianowski / Flourentzos Flourentzou / Laurent Tippenhauer	Integration of Geneva district case.
0.8	24/08/2022	Michal Pomianowski / Flourentzos Flourentzou	Integration of Cyprus case
0.9	29/08/2022	Michele Zinzi / Michal Pomianowski	Internal review and final editing of the document
1.0	31/082022	Anne Bock, AAU	Check and submission to EC

Contributors

Partner no.	Partner short name	Name of the Contributor	E-mail
1	AAU	Michal Pomianowski	mzp@build.aau.dk
1	AAU	Olena K. Larsen	ok@build.aau.dk
5	ESTIA	de Kerchove Tristan	dekerchove@estia.ch
5	ESTIA	Belias Evangelos	evangelos.belias@epfl.ch
5	ESTIA	Flourentzos Flourentzou	flourentzou@estia.ch
8	OCEN	Laurent Tippenhauer	laurent.tippenhauer@etat.ge.ch
2	POLITO	Giacomo Chiesa	giacomo.chiesa@polito.it
10	NEOGRID	Pierre Vogler-Finck	pvf@neogrid.dk
4	EMTECH	Vassilis Georgoutsos	vassilis.georgoutsos@emtech.global
6	ENEA	Michele Zinzi	michele.zinzi@enea.it

Table of Contents

Table of Figures

Table of Tables

Table of Acronyms

Acronym	Definition
API	Application Programming Interface
BMS	Building Management System
CDD	Cooling Degree Day
DEPC	Dynamic Energy Performance Certificate
DHW	Domestic Hot Water
EPC	Energy Performance Certificate
GIS	Geographic Information System
GHG	Greenhouse Gas
HDD	Heating Degree Day
HVAC	Heating Ventilation and Air Conditioning
IEQ	Indoor Air Quality
IoT	Internet of Things
KPI	Key Performance Indicator
MPV	Mean Predicted Vote
NZEB	Nearly Zero Energy Building
PG	Performance Gap
PPD	Percent People Dissatisfied
PV	Photovoltaic
RH	Relative Humidity
VOC	Volatile Organic Compound

1 Executive Summary

This report reflects on the overall preparation of all demonstration cases in E-DYCE project that will lead to DEPC assessment.

The report is divided into sections. Sections 3 to 7 elaborate individually on preparation of each country demonstration cases, respectively; Section 3 - multi apartment buildings in Geneva (Switzerland), Section 4 - residential single-family houses, kindergarten and school building in Torre Pellice (Italy), Section 5 - multi apartment buildings in Aalborg and Frederikshavn (Denmark), Section 6 - municipality office in Nicosia (Cyprus), Section 7 - Geneva district. The preparation process includes broad range of actions such as: acquaintance and description of the assessed buildings, labeling and assessment according to current national EPC schemes, end user feedback (if available), preparation of models for DEPC assessment, monitoring campaign that supports DEPC and plan for DEPC protocol integration for each pilot case.

In section 7 is summarized overview of the pilot cases integration in the dynamic simulation architecture, namely FusiX platform, and summary of web and mobile application architecture and their functionalities to access building assessment data. Building integration into middleware solution (FusiX) allows for collection, storage and analysis of buildings data for their assessment.

First, each demonstration case building is shortly described taking also into account the motivation for the monitoring, its scope and level of detail. Moreover, this section elaborates on the values of DEPC for the building and end users.

Secondly, user/tenant feedback, where available, is collected, summarized and conclusions are drawn. Collection of user feedback experiences focuses on their perception of the installation process and period when sensors are already installed and logged. These two phases are significantly different since the installation process is short and highly invasive and second period is long and low invasive. Level of detail of feedback also varies among demonstration cases and depends on user involvement and attitude to the process. Moreover, observations on the practical issues registered during the process are elaborated. For example, deviation from the original plans for monitoring and reasons for these deviations, economy, practicalities related to monitoring solutions selection and installation, data transmitting issues, COVID pandemic.

Thirdly, this report provides an overview of the type of the data being measured, number of probes used and logged from each of the demonstration case. Moreover, issues related to reliability and logging intervals of the applied commercial monitoring solutions are elaborated along GDPR and ethics issues. Moreover, monitoring process shall generate valuable information that are aligned with the DEPC assessment framework.

Finally, this report provides overview of expected DEPC framework integration both with respect to modelled (asset) and measured (operational) assessment of pilot case buildings.

This report does not include monitoring and modelled results. Monitoring and modelling results or plans for analysis of monitoring results/modelling results are available in deliverable 5.2 – 5.5 individually for each demonstration location, Switzerland, Italy, Denmark and Cyprus. Analysis of the results and building diagnosis together with recommendations for buildings operation can be found in E-DYCE D5.6. Moreover, E-DYCE D5.2 - 5.5 include more detailed insight, specification and plans for assessment of each of the demonstration cases and more detailed insight into applied monitoring solutions.

Inspection purpose and monitoring overview

The purpose of the inspections is to provide additional inputs (data collection) required to correct DEPC modelling inputs from standard (SIA, ISO) to as built/actual. These inputs may refer to:

- static parameters, for example, thermal properties of the building, assessed during the inspection to be different from building codes or technical reports on the case buildings.

- to condition of use being inspected significantly different from standard assumptions, for example, load profiles, occupation loads, set points for heating and cooling.

- technologies deviating from the standard assumption, for example, presence or no presence of shading.

- monitoring hardware (sensors and meters) providing access to live and historical data, for example, smart heat meters/meters, domestic hot water flow meters, temperature sensors.

It must be highlighted, that inspection depth and level of detail and therefore data availability to feed the models depends significantly on the type of the building and access to the spaces. For instance, inspection possibilities in public buildings, such as schools, public offices, that are generally open to the society provide much easier access than private residential buildings (apartments or houses) which require not only owner acceptance to enter but also involvement from the owner to participate in questionnaires.

The overview of monitoring activities in all pilot buildings is presented in Table 1. The additional monitoring installation in each pilot case has been planned and carried out in order to be able to conduct DEPC assessment. It must be highlighted that DEPC assessment can be also carried out partially and with respect to available data. Existing monitoring infrastructure in all demonstration cases was either insufficient or would allow for only very fragmented DEPC assessment. This is also valuable information that indicate that current monitoring infrastructure in buildings is most probably insufficient and financial investments would be required to conduct operational assessment of building performance. However, to some extend monitoring activities could rely on existing monitoring infrastructure, if present, and would allow to derive specific KPIs. This is the case in only some buildings and only to some extent. More detailed information per each specific case is provided in the following chapters 3 to 7 that cover national pilot cases situation and in E-DYCE D5.2 - D5.5. Identified level of monitoring that can be found in Table 1 for each pilot building, basic/moderate/detailed, is subjectively determined by the consortium partners working on the case buildings and taking into account their best understanding of monitoring infrastructure that could be present in the building typology represented by pilot cases and data requirements for DPEC assessment.

Table 1 Overview of monitoring availability in E-DYCE pilot buildings.

			MS3 - case studies transmitting data	Level of monitoring	Spatial factor
Building code	Location	Building type/name	Case building transmitts data	[detailed/moderate /basic]	[Building, Apartment, Room, Component]
[#]	[city, country]		[Yes/No]		
B1.1	Geneva, Switzerland	Multi apartment	Yes	Moderate	Building/Appartment
B1.2	Geneva, Switzerland	Multi apartment	Yes	Basic	Building/Appartment
B1.3	Geneva, Switzerland	Multi apartment	Yes	Detailed	Building/Appartment
B1.4	Geneva, Switzerland	Multi apartment	Yes	Detailed	Building /Room
B2.1	Torre Pelice, Italy	Municipality Kindergarten & Middle School	Yes	Detailed /Moderate	Building /Room
B2.2	Torre Pelice, Italy	High School "Liceo Valdese"	Yes	Detailed /Moderate	Building /Room
B2.3	Torre Pelice, Italy	Single family house	Yes	Detailed /Moderate	Building /Room
B2.4	Torre Pelice, Italy	Single family house	Yes	Detailed /Moderate	Building /Room
B2.5	Torre Pelice, Italy	Single family flat	Yes	Detailed /Moderate	Building /Room
B3.1	Nicosia, Cyprus	Office building	Yes	Focus on indodor climate	
B4.1	Frederikshavn, Denmark	Multi apartment, Haandbaek	Yes	Detailed	Building/Apartment/Room/Component
B4.2	Aalborg, Denmark	Multi apartment, Magisterparken	Yes	Moderate/low	Building/Apartment/Room/Component
B4.2	Aalborg, Denmark	Multi apartment, Thulevej	Yes	Moderate/low	Building/Apartment/Room/Component

Building code	Monitoring																	
	Energy					Indoor environment						Special measurements/component					On site meteo station	Nearby meteo station
	Space heating only	Domestic hot water only	Space heating&Domestic hot water (together)	Electricity	other	Temp	RH	CO2	VOC	Lux	Ohter	Window opening	PIR	U-value	PMV/PPD	Other	[Specify parameters]	[Specify parameters]
[#]																		
B1.1			Yes			Yes	Yes	No	No	No		No	No	No	No			Yes****
B1.2						Yes	Yes	No	No	No		No	No	No	No			Yes****
B1.3			Yes	Yes (building)		Yes	Yes	Yes 11 sensors	Yes (4 sensors)	Yes (8 sensors)		No	No	No	No			Yes****
B1.4			Yes			Yes	Yes	Yes (9 apartments)	No	No		No	No	No	No			Yes****
B2.1	Yes			Yes (building)		Yes	Yes	Yes**	Yes (2 rooms)	Yes (2 rooms)		Yes***	No	iv (done)	no (iv?)	DD		Yes****
B2.2	Yes			Yes (building)		Yes	Yes	Yes**	No	No		No	No	iv (done)	no (iv?)	DD	Yes****	
B2.3	will (all components ready)	will (all components ready)		Yes (building)		Yes	Yes	Yes**	No	No		Yes***	No	iv?	no	DD		Yes****
B2.4	Yes			Yes (building)		Yes	Yes	Yes**	No	No		No	No	iv?	no			Yes****
B2.5	Yes	Yes		Yes (flat)		Yes	Yes	Yes**	No	No		Yes***	No	iv (done)	no (iv?)			Yes****
B3.1						Yes	Yes	Yes	No	No		No	No	No	No		Yes*****	Yes?
B4.1	Yes	Yes	Yes	no		Yes	Yes	Yes	No	No		Yes	No	No	No	AHU	No	Yes
B4.2	Only building level		Yes (main meter and hot water, difference gives space heating)	no		Yes (few apartments)	Yes (few apartments)	Yes (few apartments)	No	No		Yes	No	No	No		No	Yes
B4.2	Only building level		Yes (main meter and hot water, difference gives space heating)	no		Yes (few apartments)	Yes (few apartments)	Yes (few apartments)	No	No		Yes	No	No	No		No	Yes

** In main rooms (not in all rooms)

*** Not in all rooms - the installed solution is not very reliable

**** Full meteo station and global irradiation (split components need to be calculated)

***** Temperature and wind speed and direction

Iv - It is expected to have specific measurements for limited periods

DD - Special degree day sensor (including outdoor temperature probe)

2 Demonstration case 1 – Multi apartment buildings in Geneva, Switzerland

2.1 Description of the demonstration cases

The Swiss case studies consist of four buildings located in different neighbourhoods in the city of Geneva. They represent the different typologies of multi-family buildings existing in Switzerland. The city itself is at the center of western Europe, on the border with France, see Figure 1.

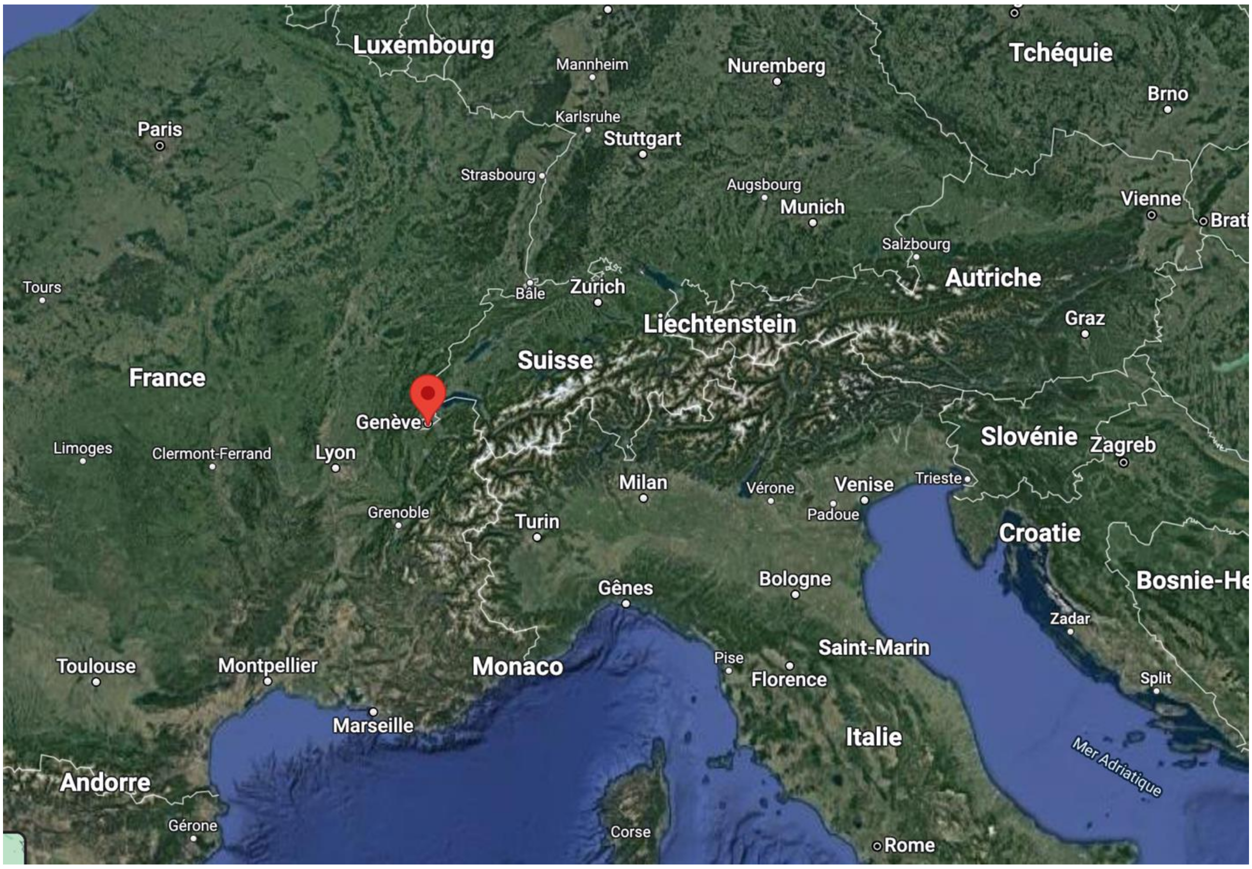


Figure 1: Geneva's geographical location

The canton of Geneva has an innovative energy policy as it requires recording the annual heat consumption of the multi-family buildings since year 1994. This database of heat consumption at the city scale allows comparisons of a targeted building according to the mean buildings' behaviour. In addition, it allows the stakeholders to test the results of political energy saving actions and follow the evolution of the energy for heating trend, see Figure 2.

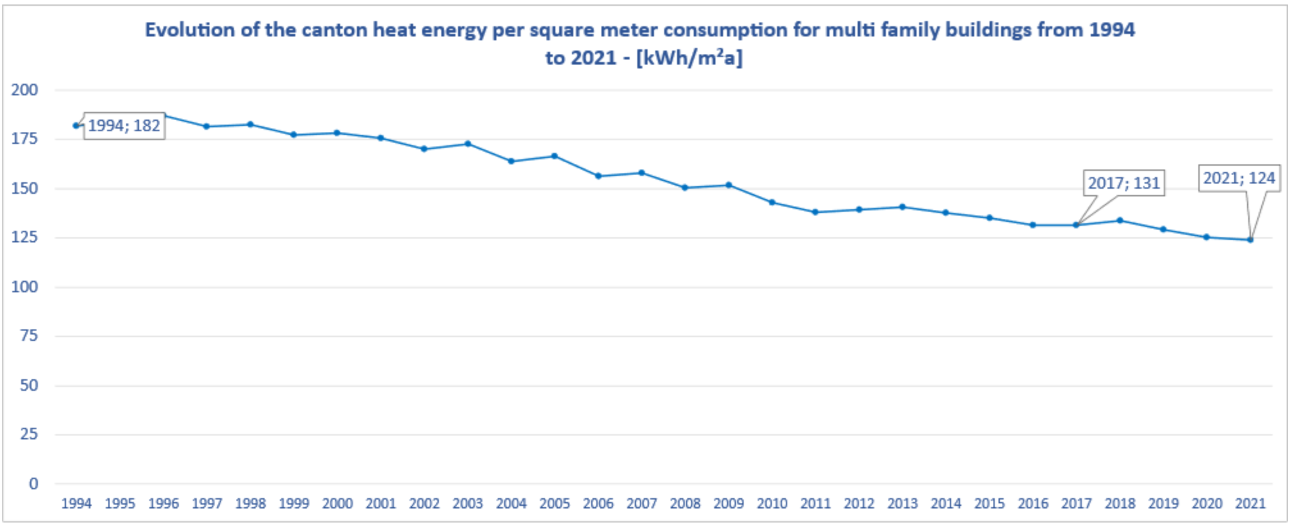
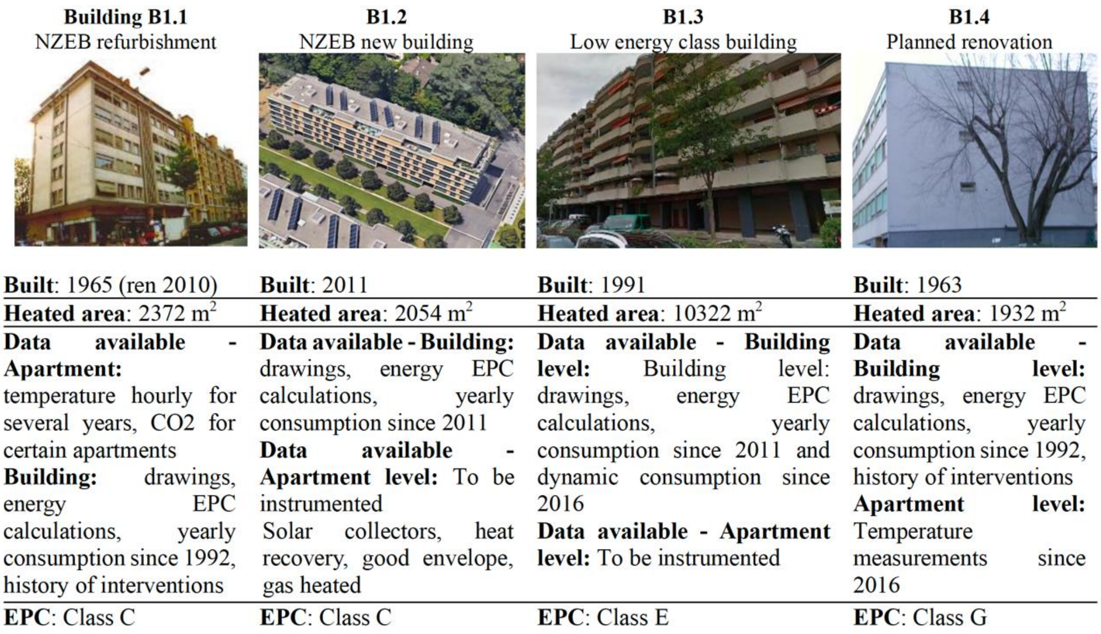


Figure 2 The mean consumption per heated square meter of the multi-family buildings in the canton of Geneva. (Data from SITG)

The case studies selected for E-DYCE in Geneva are four buildings with different EPC classes, see Figure 3. The first building (B1.1) was refurbished in 2010 with a NZEB renovation objective. The second building (B1.2) was built in 2010 with a NZEB objective. The third building (B1.3) was built in the 90's and presents a potential for optimization without deep refurbishment. Finally, the fourth building (B1.4) from the 60's with high energy consumption was selected as the fourth building as it represents the old-non refurbished buildings of the canton of Geneva. The four belong to the CPEG, which accepted them to be used as case studies for the E-DYCE project. Their total heated floor areas vary between ~2'000 m^2 and ~10'000 m^2.

The different objectives for the buildings are the following:

- B1.1: Identify the reasons for the performance gap and correct it.
- B1.2: Identify the reasons for the performance gap happening since commissioning and the comfort issues in the building
- B1.3: evaluate the possibility of decreasing energy consumption through individual actions and optimization without deep refurbishment
- B1.4: Establish a renovation roadmap that would allow commissioning without a performance gap.



Building B1.1 NZEB refurbishment	B1.2 NZEB new building	B1.3 Low energy class building	B1.4 Planned renovation
Built: 1965 (ren 2010)	**Built**: 2011	**Built**: 1991	**Built**: 1963
Heated area: 2372 m^2	**Heated area**: 2054 m^2	**Heated area**: 10322 m^2	**Heated area**: 1932 m^2
Data available - Apartment: temperature hourly for several years, CO2 for certain apartments **Building:** drawings, energy EPC calculations, yearly consumption since 1992, history of interventions	**Data available - Building:** drawings, energy EPC calculations, yearly consumption since 2011 **Data available - Apartment level:** To be instrumented Solar collectors, heat recovery, good envelope, gas heated	**Data available - Building level:** Building level: drawings, energy EPC calculations, yearly consumption since 2011 and dynamic consumption since 2016 **Data available - Apartment level:** To be instrumented	**Data available - Building level:** drawings, energy EPC calculations, yearly consumption since 1992, history of interventions **Apartment level:** Temperature measurements since 2016
EPC: Class C	**EPC**: Class C	**EPC**: Class E	**EPC**: Class G

Figure 3 Resumé of the buildings from the proposal. Please note that the EPC classes do not correspond anymore

For the need of the project, the buildings demanded a monitoring of their energy consumption as well as their indoor environment. Multiple monitoring solutions were explored for the different buildings. Most of the buildings already had pre-existing solutions, but some of them had to be completed. Generally, a good compromise between feasibility, costs and data needs was found for each individual building. The different factors considered for the monitoring choices were:

- Monitored quantities
- Costs of the monitoring options
- Remote data accessibility
- Time efficiency of monitoring installation
- Correspondence of the solution with the building owner's needs
- Fluidity of the communication with the monitoring solution provider

These aspects had different weights in the decision process for the 4 buildings monitoring solutions. For example, no new monitoring solutions were deployed in B1.2 because of the complexity and cost of implementation as for B1.3, the need for fast implementation, oriented the choice rather than the costs.

The monitoring solutions for each building are presented in Section 3.2, while a detailed description with sketches and plans is presented in E-DYCE D5.2.

The standard EPC failed to evaluate the performance of the studied buildings correctly. In the E-DYCE framework, there is hope that taking the dynamic behaviour of the building into account would allow to better anticipate the building's energy needs and consumption.

For the 2 NZEB (B1.1 and 1.2), the DEPC should allow the modification of the heating set point and allow for a better evaluation of the solar gains and ventilation losses. This could potentially aid the engineers in locating the origin of the performance gap.

In the case of the non-refurbished buildings (B1.3 and 1.4), it is intended that the inertia of the buildings and the heating setpoints evolution could allow for a better understanding of the negative performance gap. In addition, we would expect to test optimization actions on the dynamic model to anticipate their effect on the energy need and/or the comfort.

Finally, the dynamic simulations may allow the definition free-running period of the building and identify critical zones with the shorter free-running period. These zones are crucial for understanding the building's operation as they define the start and the end of heating and cooling periods.

2.1.1 Inspection protocols

All 4 buildings have been inspected, and their plans scanned and verified. All information is available both in the DEPC model and the monitoring plan of the buildings. In addition, 3 out of 4 building inspection protocols were filled (for building B1.1, 1.3 and 1.4). The inspection protocol of B1.2 is in progress and should allow for an update of the inspection protocol itself.

The filled inspection protocol can be accessed here:

https://E-DYCE.eu/e-dyce-inspection-protocol-switzerland/

Protocols allow for elaboration of critical observations from inspection (deviation from the standard expected values, lack of access/ possibility for assessment, difficulty in adapting comment to protocol structure, etc..).

Inspecting the different buildings allows the specialists to better understand their divergence with the standard EPC model. Observation of the individual radiator's valve position, the schedule of ventilation and even the number of occupants of the apartments can allow better calibration of the dynamic model. The discrepancies in standard occupation can also be identified with discussion with inhabitants.

Similarly, envelope properties may diverge by expected typical values or by the layer composition suggested by the available building plans. However, this type of inspection usually necessitates drilling in the existing walls, which was not an option at the time of inspection. However, some hypotheses from the building plan inspection were verified during the inspection of the buildings.

Finally, an on-site inspection clarifies certain aspects of the building's technical installation that can influence the operation and efficiency of the building's behaviour. The heaters' heating curve and temperature setpoint, the DHW production type and storage tank volume are good examples of elements usually only detectable through inspection of the building, at least in Switzerland.

2.2 Static EPCs

We have performed standard EPC calculation for the different buildings with the available information. We have observed that these EPCs show some discrepancies with the current building's consumption and behaviour. In fact, EPCs are generally produced when the building is built or when there is a planned refurbishment. The four EPCs were performed by ESTIA company as it is accredited to do so in Switzerland. The EPC main results are shown in Table 2.

In Switzerland, the EPC follows the national standard SIA 2031:2016 (Zürich, 2016) and allows for quantification of the overall building's energy performance as well as the envelope's performance. This leads to a double assessment: one assessment of the global energy behaviour and taking the energy flows in the building into account and one only on the building's envelope performance, without consideration of the energy vectors or potential energy production. The aim of this dual EPC is to avoid having a building with a non-efficient envelope using a heat pump and PV panels ending up with a high energy class. In the E-DYCE framework, we will only consider the global energy label as this is in line with the different countries of Europe and with other project members.

The EPC classes, ranging from A to G, are defined in Table 2, with EPgl defined in SIA 2031 for each building type. The standard weather of the geographical region is considered in the EPgl value.

Table 2 Swiss scale for EPC class ranges

Lower limit	Energy Class	Upper limit
0 EPgl <	A	≤ 0,50 EPgl
0,50 EPgl <	B	≤ 1,00 EPgl
1,00 EPgl <	C	≤ 1,50 EPgl
1,50 EPgl <	D	≤ 2,00 EPgl
2,00 EPgl <	E	≤ 2,50 EPgl
2,50 EPgl <	F	≤ 3,00 EPgl
> 3,00 EPgl	G	

The EPC results show the wide range of possible energy classes in the Geneva building stock , see Table 3.

Table 3 EPC results for the Swiss case studies

KPI	[Unit]	B1.1	B1.2	B1.3	B1.4
Global primary energy performance index (EPgl,nren)	[kWh/m2 year]	92	94	174	292
Primary energy needs for heating (EPh,nd)	[kWh/m2 year]	29	22	79	165
Primary energy needs for cooling	[kWh/m2 year]	-	-	-	-
Primary energy needs for DHW (EPacs)	[kWh/m2 year]	51	17	38	53
Primary electricity needs	[kWh/m2 year]	21	27	28	37
Ideal useful (net) energy needs for heating (QH,nd)	[kWh/m2 year]	26	21	68	131
Useful energy needs for cooling (QC,nd)	[kWh/m2 year]	-	-	-	-
Useful energy needs for DHW	[kWh/m2 year]	21	21	21	21
EPC label	-	B	B	D	F

2.3 End users (tenants) feedback

Concerning the tenants, there was very poor end user implication in all the case studies. This can be attributed to the few number of visits on site as well as a lack of interest from the tenants. As an example, a questionnaire was circulated to 25 tenants of B1.3 and only 2 of them answered, with very poor answers quality. This result was therefore unusable. Concerning the building's owner, Estia had interactions mainly with respect to the installation of monitoring solutions for the case studies B1.3 and B1.4. In addition, Estia evaluated and anticipated the installation of the new ventilation system in B1.3. This action is foreseen as an energy-efficient optimisation and its impact will be evaluated during the heating season. The building owner is implicated in this process as the owner is looking to use this optimisation solutions for other buildings as well. Focus on the end user interaction will be put with the analysis of the monitoring data and development of the dynamic models.

2.4 Practical observations

While looking for an indoor environment monitoring solution, a wide range of possibilities was available. The prices would also vary from simple to double depending on the solution provider and the possible services would differ. Monitoring solutions with remote data accessibility were chosen to avoid having many time-consuming on-site visits. This allows for easy data access but has sometimes high financial cost.

Regarding the heating and electric counter installation for B1.3 during the project, the shipment and installations suffered extensive delays. This was not anticipable as it is a combination of COVID pandemic and brake of supply chains. In addition to the delivery delays, the necessity of different service providers and their coordination increased the installation time. Finally, some technical difficulties (no 3G signal in the building's basement) just added up to the initial delays. From this experience, we have learned that counter installation and choices are crucial and that anticipation is a key factor in reducing the risks of delays.

As described above, monitoring solutions were chosen for their availability to share data online and be accessible from a platform. However, it was not known at the initial state that there would be a need for API communication. Hopefully, some providers had already such connexion implemented and connection to FusiX was possible, but some (Batnrj and Egain) didn't have that service available. This is typically an important aspect to consider for the next projects and monitoring solution choices.

Estia's headquarters are based in Lausanne, 40 minutes away from Geneva. This made the visits and possible fix of problems harder to perform on a short timescale. This would delay our reactivity to on-site issues and the possibility of quick intervention.

2.5 Monitoring specifications and plans

A general description of the monitoring choices and solutions is presented in this chapter. A detailed explanation of the sensors type, measurement accuracy as well as position in the different buildings is given in D5.2. Some solutions described here already existed in the buildings (mainly the dry bulb temperature (DBT) and relative humidity (RH) sensors in the different apartments). The additional monitoring solutions were ordered by Estia. Estia installed the environmental quality sensors, but the installation of technical sensors (heat and electricity for B1.3) was performed by a specialized company (Groupe-E).

Sensors and connected data are named according to the suggestion given in E-DYCE D3.2. At the same time, the same nomenclature approach has been followed for the developed building models to match model zones with sensor locations. Similarly, monitored variables follow the suggested nomenclature, e.g. T_db_i[C] for internal dry bulb temperature in Celsius; CO2_i[ppm] for internal CO2 ppm concentration; RH_i[%] for internal relative humidity; Q_h[kWh/m2] or [kWh] for heating needs or Q_c[kWh/m2] for cooling ones, etc.

The following Table 4 reports the main sensor types installed in the demos.

Table 4 Variables and nomenclature.

Dataloggers (variable compositions)	**Name for PRE-DYCE PG scenario**
DBT	T_db_i[C]
DBT+RH%	T_db_i[C] + RH_i[%]
DBT+RH%+CO2	T_db_i[C] + RH_i[%] + CO2_i[ppm]
DBT+RH%+Lux	T_db_i[C] + RH_i[%] + LUX_i[lx]
DBT+RH%+VOCs	T_db_i[C] + RH_i[%] + TVOC_i[ppm]
DBTex	T_db_e[C]
DBTex+External CO2	T_db_e[C] + CO2_e[ppm]
Electrical consumption (pulse)	Q_l[kWh] or Q_l[Wh]
Heat flow(pulse & suppl.return temp)	Q_h[kWh]
Surface temp.	nd
State (window open)	nd
Additional	
Routers	-
Gateways	-

The quantities of dataloggers installed per demo are reported in the following Table 5.

Table 5 Quantities of installed monitoring hardware

Dataloggers (variable compositions)	**B1.1**	**B1.2**	**B1.3**	**B1.4**
DBT+RH%	22	52	6	15
DBT+RH%+CO2			12	22
DBT+RH%+Lux				
DBT+RH%+VOCs			8	
Electrical consumption			2	
Heat flow(pulse & suppl.return temp)			1	
Gas/oil counter	1	1*	1*	1

*Monthly values only

A full description of the positions and numbers of the sensors is given in E-DYCE D5.2. Globally, for all considered buildings, not all apartments are monitored. There are usually one to two sensors per apartment. The aim of this placement was to understand the global behaviour of the whole building rather than focusing on the local discrepancies inside the same flat. An example of a monitoring plan is given in Figure 4.

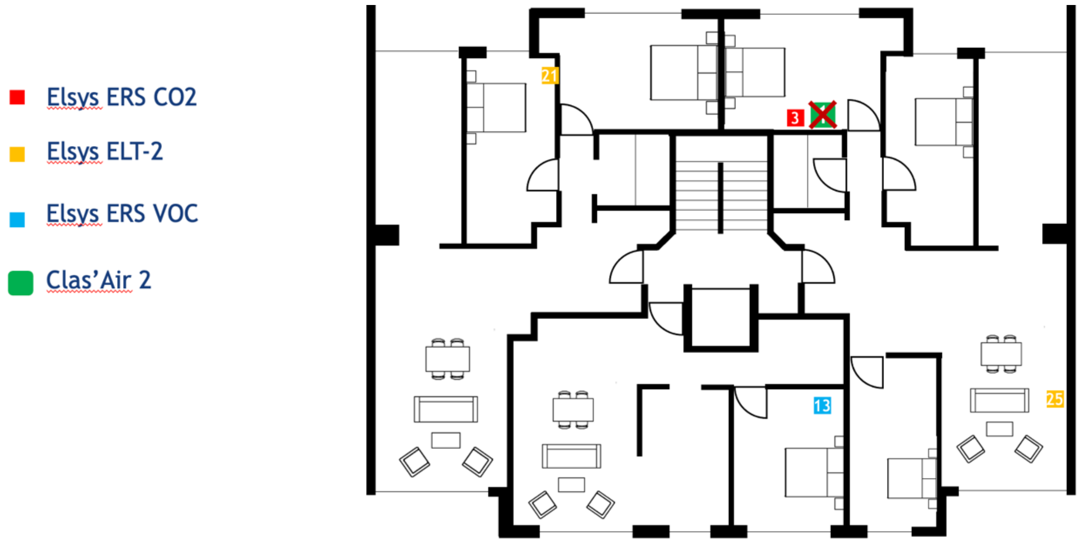


Figure 4 Monitoring plan example for B1.3.

Table 6 depicts the KPI families that are intended to be addressed in the four demo buildings. Specific KPIs within each family is identified in DEPC protocols for each pilot case.

Table 6 Overview of expected operational KPI families being addressed in the Swiss demo cases.

	KPIs			
Demo case building	Energy operation	Energy signature	Comfort/quality	Free running
B1.1	Yes -heating (weekly)	Yes -Heating	Yes	No - heating
B1.2	Yes -heating (monthly)	Yes -Heating	Yes	Yes - heating
B1.3	Yes -heating +el.(hourly)	Yes -Heating	Yes	Yes - heating
B1.4	Yes -heating (weekly)	Yes -Heating	Yes	Yes - heating

2.6 Dynamic model simulation for DEPC

The DesignBuilder software was used to build the geometry of the EnergyPlus models that were used for the dynamic simulations of the Swiss demo cases. A multi-zonal approach was adopted for the thermal zoning in order to locate and further analyze the critical zones of each building. Regarding the definition of the HVAC systems, it was decided to utilize the simple ideal loads HVAC system of EnergyPlus to reduce the models' complexity and make them compatible with the PRE-DYCE tool (E-DYCE D3.1 and D3.2).

As presented in Figure 5, also the surroundings of each building were included in the model to consider the shading effects of neighbour buildings.

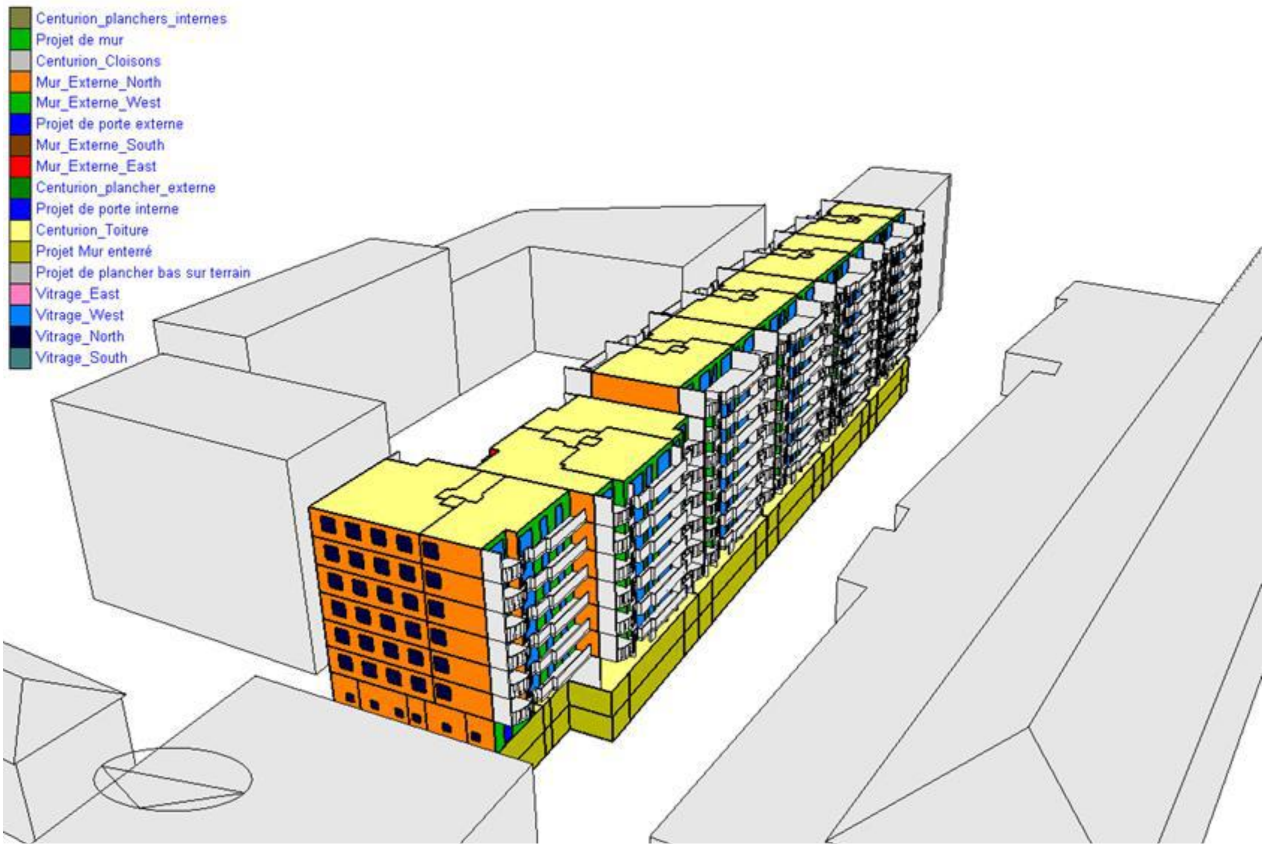


Figure 5 Three-dimensional representation of the Swiss B1.3 demo case.

For the creation of the dynamic simulation model of each Swiss demo case, it was followed the steps below:

- In the first step, a building engineer visited the building in order to:
  - Fill out the inspection protocol
  - Collect the architectural plans
  - Collect information about:
    - Energy consumption of the previous years
    - IEQ parameters of the previous years
    - Real conditions of use
  - Establish a monitoring plan after discussions with the building owners

- In the second step, the engineer developed a first version of the model using the information collected in the previous step (architectural plans, inspection protocol) and the DesignBuilder interface. The zoning of all the demo cases was at the level of the apartments. The naming of the zones was done per the monitoring plan to permit an automatic recall of outputs at different aggregation levels in the FusiX platform.

- In the third step, the model was adapted based on the observed and measured conditions of use (real indoor temperatures, ventilation rates, energy consumption, etc.). To adapt the model, the mainly adjusted parameters were the ventilation and infiltration rates, the window opening behaviour, and the use of the blinds for shading. It was considered that the model was sufficiently adapted when the difference between the simulated and measured indoor air temperatures was smaller than 1 °C and the difference between the simulated and measured energy demand was less than 5%, using the actual meteorological data. This way, the model was verified that can predict accurately enough the operational conditions of the investigated building.

- In a fourth step, the engineer adapted the model for the E-DYCE DEPC analyses by inputting Standard conditions of use (EN 16798-1).
- In a fifth step, the model was used to produce data for the DEPC-AS, DEPC-AA, and other analyses.
- In a sixth step, the models will be connected with the PRE-DYCE tool in the FusiX in order to run parametric sensitivity analyses and examine the potential of the dynamic technologies.

The above-mentioned phases may be modified in the final version of the E-DYCE methodology according to the feedback from the other demo cases.

More details about the creation and adaptation of each simulation model can be found in the E-DYCE D5.2.

2.7 DEPC framework integration

According to the specifications of the E-DYCE DEPC method the Swiss demo cases reported the majority of the KPIs presented in E-DYCE D2.4. More specifically, the existing static EPCs described the asset standard. The dynamic simulation models, when they run with the EN 16798-1 standard conditions permitted the definition of the DEPC-AS and when they run with the adapted to actual conditions permitted the definition of the DEPC-AA. Moreover, the monitoring of the buildings permitted the elaboration of the DEPC-O. The following tables summarize the KPIs that were calculated in each demo case.

Table 7 The colour legend for the Tables 8-11.

Indicator acc. to E-DYCE D2.4	Explanation
✓	Potentially available for some demo buildings, but not for the one in focus
✓ (green)	Potentially available for the specific demo building
✓ (yellow)	Uncertain availability for the specific demo building
✕	Unavailable for all demo buildings

Table 8 The expected coverage of KPIs within DEPC framework integration for the B1.1 (NZEB refurbished apartment building) demo case.

For tenants							
KPI		Assessment schema				Evaluation period	
	Symbol	EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl			✗	✗	month	year
Final energy need for heating	f_Q_h			✓	✓	week	year
Final energy need for cooling	f_Q_c			✗	✗	week	year
Final energy need for DHW	f_Q_dh			✗	✓	week	year
Final energy need for heating for an average space in the building	f_Q_h_av			✓	✓	week	year
Final energy need for cooling for an average space in the building	f_Q_c_av			✗	✗	week	year
Operative temperature	t_op_i			✓	✓	week	
CO_2 concentration	CO2			✗	✓	week	

For certification party/Energy service specialist							
KPI		Assessment schema				Evaluation period	
	Symbol	EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl	✓	✗	✗	✗	month	year
Primary energy need for heating	Q_h	✓	✓	✓	✓	week/month	year
Primary energy need for cooling	Q_c	✗	✗	✗	✗	week/month	year
Primary energy need for DHW	Q_dh	✓	✗	✗	✓	week/month	year
Primary electricity need for running technical installations	Q_tech	✓	✓	✓	✓	week/month	year
Primary electricity need for lighting (if relevant)	Q_l	✓	✓	✓	✗	week/month	year
Primary energy need for heating for an average space in the building	Q_h_av	✗	✓	✓	✗	week/month	year
Primary energy need for cooling for an average space in the building	Q_c_av	✗	✗	✗	✗	week/month	year
Primary energy need for heating for the critical zone	Q_h_cr	✗	✓	✓	✗	week/month	year
Primary energy need for cooling for the critical zone	Q_c_cr	✗	✗	✗	✗	week/month	year
Energy signature, global solar correlated	EN_SIG_2D	✗	✓	✓	✓	month	year
Energy signature, global solar correlated for the critical zone (heating)	EN_SIG_2D_h	✗	✗	✗	✗	week/month	year
Energy signature, global solar correlated for the critical zone (cooling)	EN_SIG_2D_c	✗	✗	✗	✗	week/month	year
Fictious Energy need for free-running mode (cooling)	FICT_COOL	✗	✓	✓	✗	week/month	year
Fictious Energy need for free-running mode (heating)	FICT_HEAT	✗	✓	✓	✗	week/month	year
Number of free-running hours (cooling season)	n_fr_c	✗	✗	✗	✗	week/month	year

Number of free-running hours (heating season)	n_fr_h	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (cooling season)	n_fr_cr_c	✗	✗	✗	✗	week/month	year
Number of free-running hours for critical room (heating seson)	n_fr_cr_h	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for heating season	n_co2_h_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for cooling season	n_co2_c_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III, for heating season	n_co2_h_aIII	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I for the zone with maximum heating/cooling demand	n_co2_cr_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III for the zone with minimum heating/cooling demand	n_co2_cr_aIII	✗	✓	✓	✓	week/month	year
Operative temperature in the critical zone for heating season	T_op_cr_h_i	✗	✓	✓	✓	week	year
Operative temperature in the critical zone for cooling season	T_op_cr_c_i	✗	✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for heating		✗	✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for cooling		✗	✓	✓	✓	week	year

Table 9 The expected coverage of KPIs within DEPC framework integration for the B1.2 (New NZEB apartment building) demo case.

For tenants							
KPI	**Symbol**	**Assessment schema**				**Evaluation period**	
		EPC	**DEPC-AS**	**DEPC-AA**	**DEPC-O**	**Min**	**Max**
Global energy performance index	Q_gl			✗	✗	month	year
Final energy need for heating	f_Q_h			✓	✓	week	year
Final energy need for cooling	f_Q_c			✗	✗	week	year
Final energy need for DHW	f_Q_dh			✗	✓	week	year
Final energy need for heating for an average space in the building	f_Q_h_av			✓	✓	week	year
Final energy need for cooling for an average space in the building	f_Q_c_av			✗	✗	week	year
Operative temperature	t_op_i			✓	✓	week	
CO_2 concentration	CO2			✗	✓	week	

For certification party/Energy service specialist							
KPI	**Symbol**	**Assessment schema**				**Evaluation period**	
		EPC	**DEPC-AS**	**DEPC-AA**	**DEPC-O**	**Min**	**Max**
Global energy performance index	Q_gl	✓	✗	✗	✗	month	year
Primary energy need for heating	Q_h	✓	✓	✓	✓	month	year

Primary energy need for cooling	Q_c	✗	✗	✗	✗	week/month	year
Primary energy need for DHW	Q_dh	✓	✗	✗	✓	week/month	year
Primary electricity need for running technical installations	Q_tech	✓	✓	✓	✓	week/month	year
Primary electricity need for lighting (if relevant)	Q_l	✓	✓	✓	✗	week/month	year
Primary energy need for heating for an average space in the building	Q_h_av	✗	✓	✓	✗	week/month	year
Primary energy need for cooling for an average space in the building	Q_c_av	✗	✗	✗	✗	week/month	year
Primary energy need for heating for the critical zone	Q_h_cr	✗	✓	✓	✗	week/month	year
Primary energy need for cooling for the critical zone	Q_c_cr	✗	✗	✗	✗	week/month	year
Energy signature, global solar correlated	EN_SIG_2D	✗	✓	✓	✓	month	year
Energy signature, global solar correlated for the critical zone (heating)	EN_SIG_2D_h	✗	✗	✗	✗	week/month	year
Energy signature, global solar correlated for the critical zone (cooling)	EN_SIG_2D_c	✗	✗	✗	✗	week/month	year
Fictious Energy need for free-running mode (cooling)	FICT_COOL	✗	✓	✓	✗	week/month	year
Fictious Energy need for free-running mode (heating)	FICT_HEAT	✗	✓	✓	✗	week/month	year
Number of free-running hours (cooling season)	n_fr_c	✗	✗	✗	✗	week/month	year
Number of free-running hours (heating season)	n_fr_h	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (cooling season)	n_fr_cr_c	✗	✗	✗	✗	week/month	year
Number of free-running hours for critical room (heating seson)	n_fr_cr_h	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for heating season	n_co2_h_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for cooling season	n_co2_c_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III, for heating season	n_co2_h_aIII	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I for the zone with maximum heating/cooling demand	n_co2_cr_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III for the zone with minimum heating/cooling demand	n_co2_cr_aIII	✗	✓	✓	✓	week/month	year
Operative temperature in the critical zone for heating season	T_op_cr_h_i	✗	✓	✓	✓	week	year
Operative temperature in the critical zone for cooling season	T_op_cr_c_i	✗	✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for heating		✗	✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for cooling		✗	✓	✓	✓	week	year

Table 10 The expected coverage of KPIs within DEPC framework integration for the B1.3 (Low energy class apartment building) demo case.

For tenants							
KPI		**Assessment schema**				**Evaluation period**	
	Symbol	**EPC**	**DEPC-AS**	**DEPC-AA**	**DEPC-O**	**Min**	**Max**
Global energy performance index	Q_gl			×	×	month	year
Final energy need for heating	f_Q_h			✓	✓	week	year
Final energy need for cooling	f_Q_c			×	×	week	year
Final energy need for DHW	f_Q_dh			×	✓	week	year
Final energy need for heating for an average space in the building	f_Q_h_av			✓	✓	week	year
Final energy need for cooling for an average space in the building	f_Q_c_av			×	×	week	year
Operative temperature	t_op_i			✓	✓	week	
CO_2 concentration	CO2			×	✓	week	
For certification party/Energy service specialist							
KPI		**Assessment schema**				**Evaluation period**	
	Symbol	**EPC**	**DEPC-AS**	**DEPC-AA**	**DEPC-O**	**Min**	**Max**
Global energy performance index	Q_gl	✓	×	×	×	month	year
Primary energy need for heating	Q_h	✓	✓	✓	✓	week/month	year
Primary energy need for cooling	Q_c	×	×	×	×	week/month	year
Primary energy need for DHW	Q_dh	✓	×	×	✓	week/month	year
Primary electricity need for running technical installations	Q_tech	✓	✓	✓	✓	week/month	year
Primary electricity need for lighting (if relevant)	Q_l	✓	✓	✓	×	week/month	year
Primary energy need for heating for an average space in the building	Q_h_av	×	✓	✓	×	week/month	year
Primary energy need for cooling for an average space in the building	Q_c_av	×	×	×	×	week/month	year
Primary energy need for heating for the critical zone	Q_h_cr	×	✓	✓	×	week/month	year
Primary energy need for cooling for the critical zone	Q_c_cr	×	×	×	×	week/month	year
Energy signature, global solar correlated	EN_SIG_2D	×	✓	✓	✓	month	year
Energy signature, global solar correlated for the critical zone (heating)	EN_SIG_2D_h	×	×	×	×	week/month	year
Energy signature, global solar correlated for the critical zone (cooling)	EN_SIG_2D_c	×	×	×	×	week/month	year
Fictious Energy need for free-running mode (cooling)	FICT_COOL	×	✓	✓	×	week/month	year
Fictious Energy need for free-running mode (heating)	FICT_HEAT	×	✓	✓	×	week/month	year
Number of free-running hours (cooling season)	n_fr_c	×	×	×	×	week/month	year

Number of free-running hours (heating season)	n_fr_h	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (cooling season)	n_fr_cr_c	✗	✗	✗	✗	week/month	year
Number of free-running hours for critical room (heating seson)	n_fr_cr_h	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for heating season	n_co2_h_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for cooling season	n_co2_c_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III, for heating season	n_co2_h_aIII	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I for the zone with maximum heating/cooling demand	n_co2_cr_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III for the zone with minimum heating/cooling demand	n_co2_cr_aIII	✗	✓	✓	✓	week/month	year
Operative temperature in the critical zone for heating season	T_op_cr_h_i	✗	✓	✓	✓	week	year
Operative temperature in the critical zone for cooling season	T_op_cr_c_i	✗	✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for heating		✗	✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for cooling		✗	✓	✓	✓	week	year

Table 11 The expected coverage of KPIs within DEPC framework integration for the B1.4 (Non-insulated apartment building with planned renovation) demo case.

For tenants							
KPI	**Symbol**	**Assessment schema**				**Evaluation period**	
		EPC	**DEPC-AS**	**DEPC-AA**	**DEPC-O**	**Min**	**Max**
Global energy performance index	Q_gl			✗	✗	month	year
Final energy need for heating	f_Q_h			✓	✓	week	year
Final energy need for cooling	f_Q_c			✗	✗	week	year
Final energy need for DHW	f_Q_dh			✗	✓	week	year
Final energy need for heating for an average space in the building	f_Q_h_av			✓	✓	week	year
Final energy need for cooling for an average space in the building	f_Q_c_av			✗	✗	week	year
Operative temperature	t_op_i			✓	✓	week	
CO_2 concentration	CO2			✗	✓	week	

For certification party/Energy service specialist							
KPI	**Symbol**	**Assessment schema**				**Evaluation period**	
		EPC	**DEPC-AS**	**DEPC-AA**	**DEPC-O**	**Min**	**Max**
Global energy performance index	Q_gl	✓	✗	✗	✗	month	year
Primary energy need for heating	Q_h	✓	✓	✓	✓	week/month	year

Primary energy need for cooling	Q_c	✗	✗	✗	✗	week/month	year
Primary energy need for DHW	Q_dh	✓	✗	✗	✓	week/month	year
Primary electricity need for running technical installations	Q_tech	✓	✓	✓	✓	week/month	year
Primary electricity need for lighting (if relevant)	Q_l	✓	✓	✓	✗	week/month	year
Primary energy need for heating for an average space in the building	Q_h_av	✗	✓	✓	✗	week/month	year
Primary energy need for cooling for an average space in the building	Q_c_av	✗	✗	✗	✗	week/month	year
Primary energy need for heating for the critical zone	Q_h_cr	✗	✓	✓	✗	week/month	year
Primary energy need for cooling for the critical zone	Q_c_cr	✗	✗	✗	✗	week/month	year
Energy signature, global solar correlated	EN_SIG_2D	✗	✓	✓	✓	month	year
Energy signature, global solar correlated for the critical zone (heating)	EN_SIG_2D_h	✗	✗	✗	✗	week/month	year
Energy signature, global solar correlated for the critical zone (cooling)	EN_SIG_2D_c	✗	✗	✗	✗	week/month	year
Fictious Energy need for free-running mode (cooling)	FICT_COOL	✗	✓	✓	✗	week/month	year
Fictious Energy need for free-running mode (heating)	FICT_HEAT	✗	✓	✓	✗	week/month	year
Number of free-running hours (cooling season)	n_fr_c	✗	✗	✗	✗	week/month	year
Number of free-running hours (heating season)	n_fr_h	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (cooling season)	n_fr_cr_c	✗	✗	✗	✗	week/month	year
Number of free-running hours for critical room (heating seson)	n_fr_cr_h	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for heating season	n_co2_h_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for cooling season	n_co2_c_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III, for heating season	n_co2_h_aIII	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I for the zone with maximum heating/cooling demand	n_co2_cr_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III for the zone with minimum heating/cooling demand	n_co2_cr_aIII	✗	✓	✓	✓	week/month	year
Operative temperature in the critical zone for heating season	T_op_cr_h_i	✗	✓	✓	✓	week	year
Operative temperature in the critical zone for cooling season	T_op_cr_c_i	✗	✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for heating		✗	✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for cooling		✗	✓	✓	✓	week	year

3 Demonstration case 2 – residential and school case buildings, Torre Pellice, Italy

3.1 Description of the demonstration cases

The Italian demonstrator consists of five buildings in Torre Pellice, a small Municipality in the North-West of Italy, Piedmont Region – see Figure 6. It is located in a piedmont site on the valley floor of Val Pellice. Considering the local climate, it corresponds to class F according to the Italian Heating Degree Day_{20} (HDD) classification elaborated for Energy retrofitting purposes and EPC – DPR 412/1993 Tab. A and further modifications support the national regulations to reduce energy consumption (Art.4, Com. 4 L.10/91). Climate Class F corresponds to the colder sites, with HDD higher than 3000. In this specific zone, differently from the other ones (A, B, C, D, E), there are no limits on the daily number of hours of activation of the heating system, while the heating season is also not fixedly defined. About 13% of the Italian Municipalities are in Class F (data subject to minor changes over the years due to progressive aggregation of smaller Municipalities).

Figure 6 Torre Pellice's geographical location.

Comparing the Torre Pellice Municipality with all Italian Municipalities – see Figure 7, it is evident that its dimension is in line with most of the other Municipalities and that it represents a very interesting demonstrator for replicability. From the energy point of view, the Municipality has started to renovate its building stock, for example, the ongoing retrofitting of its nursery school building, to increase energy efficiency and reduce energy consumption.

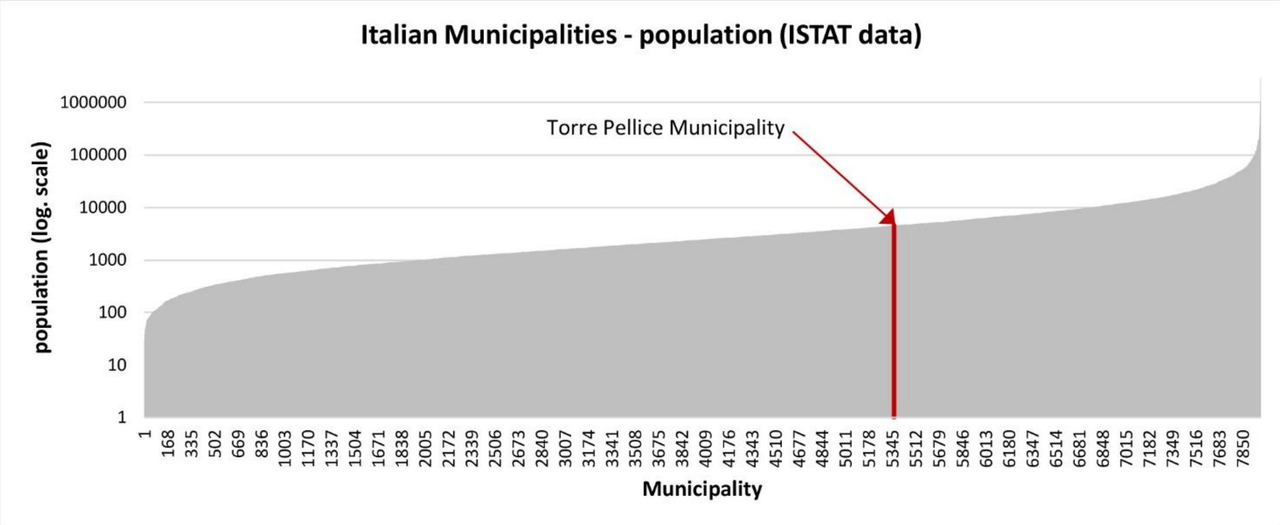


Figure 7 The distribution of the almost 8000 Italian Municipalities for the population. ***The logarithmic scale of the axis perfectly shows that Torre Pellice is representative of the majority of Italian cases, the majority of municipalities in the same dimensional range. (Elaboration on ISTAT data).***

Focusing on the Italian demonstrators, see Figure 8, it includes two schools and three residential buildings located in a small Municipality in the Piedmont Region, situated in the Pellice mountain valley. Different building typologies were selected to demonstrate the applicability of the E-DYCE platform. During the initial project stages, Italian demo buildings are expected to be two schools and two residential buildings. However, the unavailability of one of the schools due to structural problems (it is now under deep renovation) required an adaptation of the demonstrator by substituting the original school with a new one and including an extra residential unit to increase the capacity of the demonstrator in representing local typical building typologies.

The five identified buildings, see Figure 8, are:

- Two schools, the Municipal Kindergarten and Middle school building, representative of typical Italian school buildings of the second half of the XX century, with an open possibility to future renovations, and the “Liceo Valdese” high school, a historical building of the beginning of the XIX century with a high potential for IEQ implementation, but with the typical limitations for future renovation actions due to the historical value;
- Three residential buildings representative of different house typologies of small municipality residential units and various family organisations: a single-family house of the second half of the XX century, a bi-family home of the beginning of the XX century, both inhabited by a family with children of different ages, and a flat in a terraced house derived by the retrofit of a typical local rural building (built initially before the XX century) and inhabited by a sole person supporting different scheduling and space usages.

The residential building selection process was managed by TPM by a public inquiring open for free candidatures via the Municipality’s web and communication channels. The final buildings represent specific solutions of the Italian territory focusing on medium-to-small municipality areas. Thanks to three different typologies and original construction ages, they define a sort of everyday residential typology, composed of progressive implementations and with a non-homogeneous system solution that is representative of these housing solutions that the Italian photographer Luigi Ghirri defined to be the forgotten little residential spaces that generate a sort of family photo album [1].

B2.3 is a typical single-family house of the mid of XX century. It is characterised by the main floor, a not-heated basement with accessible storage spaces, and a hot roof. B2.4 is a typical residential villa built in this area at the beginning of the past century, characterised by two living floors (ground and first), a non-heated buried basement and a cold roof. The monitored areas are the ground floor and half of the first one. B2.5 is a residential flat with a double characterisation. On the one side, the original building (gneiss walls), adapted for residential uses with contemporary windows and confining with a cold roof and a garage floor, and, on the other side, a new, deeply renovated part with a hot roof and with a pavement on the ground.
The school buildings represent two common school building typologies: the first was built in the second half of the XX century with an armoured-concrete structure and brick walls, while the second school is historically characterised by typical building technologies before the XX century, with structural masonry walls and a very high internal heat capacity. B2.1 comprises a ground floor (kindergarten) and three upper floors (middle school) with a cold roof. It is connected to a small district heating system serving another school, the municipal library and a public art gallery. The other school building, B2.2 was built in 1836 and is a historically recognised building subjected to superintendence protection. The walls are not thermally insulated. Nevertheless, all rooms have thermostat valves increasing the energy efficiency at the control level. This school has a specific internal organisation that is not common in Italy, but adapted from other European contexts, based on the organisation of interior spaces for topics rather than for classes. It is composed of two floors and a not-heated buried basement.

B2.1	B2.2	B2.3	B2.4	B2.5
Kindergarten and Middle school building	High school Liceo Valdese	Private residential building	Private residential building	Private residential building (flat)
				
Built: 1975 (not renovated)	**Built**: 1836	**Built**: about 1950 (light renovation in 2015)	**Built**: about 1900 (light renovation in 2019)	**Built**: before XX century (renewed about 1940, small recent renovation – heater and spaces)
Heated area: 2150 m^2	**Heated area**: 800 m^2 (gross, about 550 m^2 net)	**Heated area**: 135 m^2	**Heated area**: 190 m^2	**Heated area**: about 90 m^2
Data available - Building level: energy bills **Data available - Apartment level:** **Idea** to renovate it toward NZEB during next 10 years **Potential** to increase IEQ and IAQ due to monitoring data and informed user actions	**Data available - Building level:** general map, energy bills **Data available - Apartment level:** plan and bills **Potential** to increase IEQ due to monitoring data, identification of light retrofitting scenarios impacts	**Data available - Building level: N/A** **Data available - Apartment level:** energy bills, EPC before light renovation **Definition** of light retrofitting impacts and reduction in performance gap optimisation **Suggesting** full renovation roadmap	**Data available - Building level:** N/A **Data available - Apartment level:** energy bills, EPC before light renovation **Definition** of light retrofitting impacts **Reduction** in performance gap thanks to optimisation	**Data available - Building level:** N/A **Data available - Apartment level:** energy bills. **Definition** of light retrofitting impacts **Reduction** IEQ suggestions, definition of light retrofitting scenario impacts; reduction in EPC performance gap
EPC: N/A	**EPC**: N/A	**EPC** - Class E - 11/06/2015	**EPC** - Class E - 06/29/2018	**EPC**: N/A

Figure 8 Resumé of the Italian demonstration buildings.

To support E-DYCE advanced functionalities, demonstration buildings are expected to support monitoring data acquisition. Nevertheless, none of the demo buildings has an intelligent monitoring system, including environmental and energy use, and can be accessible. For this reason, a smart monitoring system in all buildings is defined and installed for the E-DYCE project. The monitoring system was determined to allow:

- High replicability being based on a commercially available solution
- Scalable and modular architecture
- The possibility to be accessed remotely
- Storage capacity
- The possibility of preventing data losses (e.g. 1 redundant storage capacity; e.g. 2 avoid data losses during potential connection losses)
- The possibility of reducing the need for a fixed energy plug (battery) to reduce installation costs and increase the acceptability by the end-users
- Cost/benefit ratio to support replicability
- High-security level
- The possibility of having a SIM-based gateway independent of local networks (facultative).

The selected solution is based on the Capetti Electronics Winecap commercial system composed of a modular system comprising dataloggers with different internal or external probe configurations. The dataloggers work with a battery plug and have a local storage capacity to support data retrieval in case of cloud data losses and preserve the monitoring functionalities without the connection of the local gateway. The solution includes specific SIM-based gateways providing the collection and transmission of data to the Capetti web interface, allowing the second level of data storage to be accessible via the Winecap portal (in case gateway does not read a datalogger for a given period, but the latter is still monitoring locally). In that case, the data will be collected, transmitted and stored on the cloud when the connection is re-established, minimising the risk of data losses. The gateway modules require an electrical plug connection; similarly, the CO2 external probe (only one installed in the north façade of the B2.1 school) also requires an external electrical plug due to their higher uses. The web service based on the SOAP protocol [2] allows for a strong security level and high reliability and enables remote connections to support the potential FusiX integration for all the demos. Six gateways have been installed in the five demos (two in the B2.1 school due to the higher number of connected dataloggers). The system is expected to submit data to the server each hour, even if each probe may be (even remotely) programmed to acquire data at smaller intervals. The final data acquisition granularity will be selected, even if cloud data availability may be slightly delayed.
Additionally, a meteorological station with a cloud service and an API interface has also been installed (on B2.2) to support the collection of sufficient data to feed the generation of actual meteorological years (AMY) to support simulation usages. The meteorological station comprises a Thies Climate US module and a Delta Ohm pyranometer (class 1), allowing real-time communications. The system has a battery with a PV panel to cover potential blackout periods of the primary electrical connection.

A deeper description of the monitoring system is presented in E-DYCE D5.4.

Thanks to the monitoring system mentioned above and the definition of building models to support dynamic simulations of the demos under typical and actual weather conditions via EnergyPlus, it can be possible to offer access to specific DEPC values among the ones defined by the E-DYCE protocol reported in the related E-DYCE D2.4. We expect to support all demo buildings' analysis of IEQ values in the building and an energy analysis (heating consumption), including the performance gap between monitored and simulated data and thermal comfort. Additionally, we will analyse the free-running thermal comfort in summer to provide suggestions and define the fictitious cooling indicator. We may support tests on the impact that changes (e.g. increasing/adding thermal insulation on walls or roofs; changing windows; etc.) may have on simulated KPIs. The energy signature will be calculated together with an analysis of DEPC parameters listed below in this report.

3.1.1 Inspection protocols

All buildings have been inspected several times thanks to the support of TPM in organising POLITO accesses and to the kindness of all building users to collect specific information. For all buildings, available geometrical and cadastre data have been retrieved, together with general information known by the end-users. During the inspection visits, building dimensions have been verified by also using smart Leica Disto X4, while specific information has been collected via surveys, interviews and discussions. This exchange with end-users is continuing, supporting particular requests, e.g. Q&A and in-situ check during the model calibration process and maintaining active communication with demo users. Additionally, even if these inspection actions and correlated model development have been done before, we have filled three over five inspection protocols to give consistency to the E-DYCE proposed methodology (see WP2 deliverables). In particular, the inspection protocol format has been filled for the public-school building (the Kindergarten and Middle school building) and two over three residential demo buildings.

The filled inspection protocols can be accessed here:

https://E-DYCE.eu/e-dyce-inspection-protocol-italy/

The inspection phase is essential for developing a feasible model/analysis of a building, underlining several differences between expected values and in-situ retrieved ones. This observation considers envelope data (e.g., expected typical wall configurations) and operational aspects, modifying the standard values with adapted-standard ones following building users' specific behaviours. Such as underlined during the model verification phase, the definition of inspection-modified values is essential to increase the feasibility, but not in all cases. This analysis may support good outcomes. In residential spaces, for example, the occupancy profile is difficult to be adapted to actual uses and is not based on rigid schedules like in schools. Even for the kindergarten, the fact that several children (variable number) go home before the afternoon nap generates unpredictable divergencies. The latter is also increased because small children have a less defined organisation of activities, including outdoor and everyday activities in the larger room, merging the different classes.

Similarly, envelope properties may diverge by expected typical values or by the layer composition suggested by the building owners. For example, demo B2.1 was expected to have a not-insulated cavity wall, considering its construction period and correlated typical sample. Nevertheless, during the installation of the mechanical ventilation units, the walls were drilled to install the inlet and outlet air channels, exposing a different configuration with about 6-8 cm of insulation covering the cavity. For the same demo, some U-value in-situ measurements were also performed using the LSI monitoring kit (2 external surface temperature probes, an internal surface temperature probe and a surface heat flux meter probe), confirming the light insulation layer is present in the school walls.

Focussing on the inspection plan protocol, it is near to protocols supported for Italian applications by national validated commercial software (e.g. Termolog® or Edilclima®). However, these tools have a CAD geometrical interface that substitutes the spreadsheet collection of geometrical elaborated data with the possibility to easily manage complex surfaces or the subdivision in thermal zones or in units (with the opportunity to connect existing 3D or 2D sources with the EPC preparation phase). The proposed protocol is nearer to tools like DOCET, which can support the simplified calculation versions of the UNI/TS 11300 for small residential units. Potentially, it can be helpful to allow to fill geometrical data by including an alternative drawing-based approach. Other differences refer to the material lists that in Italian commercial software are larger and adapted to local materials and typical technological elements (e.g. looking at these tools, it is possible to retrieve different solutions helping identify hypothetical envelope characteristics), including a sizeable commercial list of windows. From the thermal bridge point of view, Italian commercial tools help automate the elaboration processes by merging envelope geometries and the advanced FEM internal tool. Similarly, regarding system data, national tools include values from UNI/TS 11300-2, -3, -4, and -5, supporting the simplified (or the advanced) calculation-related phases, including the four losses' levels (emission, regulation, distribution, generation). Similarly, tools include an extensive list of the most diffused commercially available heaters, coolers and DHW independent boilers, reducing the data collection time. Finally, it can be possible to include extra data related to the nominal heating power in the inspection protocol. Concerning the dynamic model, some additional inputs may refer to the modified standard conditions, including, when possible, extra data about occupancy (density) and scheduling profiles (presence, heating system activations, etc.), even if this additional information needs to be carefully considered to avoid an increase in the filling complexity.

3.2 Static EPCs

In Italy EPCs are generally produced for building sale or renting purposes or for specific energy-correlated incentives and may not reflect all the improvements done after property passages. EPCs may show some discrepancies with the current building state after small retrofitting or the change of the heating system. Focussing on the three residential demo buildings, we have looked for them at the Piedmont Region EPC registry. One of the buildings has an expired EPC, being the heater, a pellet-based automatic charge system, allowing to obtain an APE – APE is the Italian acronym for EPC – valid for only one year. Small retrofitting actions have been developed this year, thanks also to the E-DYCE continuous exchange of information with end-users to improve their energy efficiency, including an insulation layer positioned in the under-roof space on the extrados of the last floor slab. The existing EPC is assumed for this analysis. The second residential building has a valid EPC. Nevertheless, this summer, the owner is changing the heating system to a more energy-efficient one, in line with E-DYCE's ongoing discussions to support end-users in self-improving their energy efficiency. For this reason, it is hoped to receive an upgraded version of the APE for this building in the following months. At present, the existing one is assumed. Finally, the third residential building doesn't have an APE. The building reports an old EPC, officially still valid but not upgraded to current building conditions. The building has been recently strongly retrofitted, including a new wing, and the heated system has been modified. For this reason, POLITO has commissioned the development of an APE based on E-DYCE collected data to support static data acquisition.

Concerning the two school buildings, one (B2.2) has a valid EPC. During the last few years, this building only included remote-controlled Thermo valves on radiators, increasing the regulation efficiency of the system. Nevertheless, the existing certification is assumed because the latter is based on local typical envelope data and the APE already mentioned single-zone control. The other school building (B2.1) doesn't has an EPC. Being the municipality not interested in establishing this certification, POLITO has commissioned the development of an APE without officially depositing it to the regional registry and based on the E-DYCE collected input data for this building. In this case, being a tertiary public building, the certification includes lighting and more detailed system data.

Hence, POLITO has collected/supported independent-elaborated EPC data for all buildings to be compared with DEPC elaborated ones during the next project year, in line with project objectives. It is also important to remind that during E-DYCE actions, POLITO cannot act on these demos on system actuations while POLITO supports improvements on IEQ and summer free-running modes. Nevertheless, as mentioned above, several demo end-users have supported self-energy efficiency actions, underlining how more attentive and actual user support based on energy performance interaction may also lead to conscious end-user-driven interventions.

Italian EPC rates buildings considering an energy efficiency scale ranging from class A to class G; see the Italian scale for primary energy use in EPC obtained by comparing a given building versus its reference building, see Table 12. The five considered buildings are located in Piedmont, a region already connected to the SIAPE central system collecting EPCs into the EPC national cadastre managed by ENEA , see E-DYCE D1.1.

Table 12 Italian scale for primary energy use in EPC

Lower limit	Energy Class	Upper limit
	A4	≤ 0,40 EPgl
0,40 EPgl <	A3	≤ 0,60 EPgl
0,60 EPgl <	A2	≤ 0,80 EPg
0,80 EPgl <	A1	≤ 1,00 EPgl
1,00 EPgl <	B	≤ 1,20 EPg
1,20 EPgl <	C	≤ 1,50 EPg
1,50 EPgl <	D	≤ 2,00 EPgl
2,00 EPgl <	E	≤ 2,60 EPgl
2,60 EPgl <	F	≤ 3,50 EPg
> 3,50 EPgl	G	

Basic EPC information is extracted by the APEs and reported in Table 13 below.

Table 13 Italian scale for primary energy use in EPC.

KPI	[Unit]	B2.1	B2.2	B2.3	B2.4	B2.5
Global primary energy performance index (EPgl,nren)	[kWh/m2 year]	277.28	37.62 (EPL)	232.64 (EPL)	261.31	338.88
EPgl,ren	[kWh/m2 year]	12.21	-	-	0.08	3.25
Primary energy needs for heating (EPh,nd)	[kWh/m2 year]	175.92	37.41 (EPi,r)	213.92 (EPi,r)	219.24	317.96
Primary energy needs for cooling	[kWh/m2 year]	-	-	-	-	-

Primary energy needs for DHW (EPacs)	[kWh/m2 year]	18.19	0.21	18.72	(42.07)	20.92
Primary electricity for running technical installations (EPnren)	[kWh/m2 year]	0.27 (ventilation) 1.2 (transport)	-	-	-	-
Primary electricity needs for lighting (if relevant)	[kWh/m2 year]	27.86 (EPnren)	-	-	-	-
Ideal useful energy needs for heating (QH,nd)	[kWh/m2 year]	(175.91)	32.81	161.73	-	(235.82)
Useful energy needs for cooling (QC,nd)	[kWh/m2 year]	-	-	-	-	-
Useful energy needs for DHW	[kWh year]	10792.40	636.32	1737.26	-	1663.21
Summer thermal quality		II	I	I	(low)	II
EPC label	-	E	C	E	E	F

Looking at the retrieved data, the historic high school building shows a positive performance (Class C), while the recent school is labelled class E. At the same time, residential houses have lower performances (Class E and F), potentially requiring specific retrofitting actions by the owners to reduce energy needs.

3.3 End-user (tenants) feedback

Users' have been involved in numerous visits allowing for the possibility to support a constant collection of feedback experiences. All involved residential users demonstrated a great interest in participating in the study and helped in collecting information, including, when known, discussions on current building conditions, past or future retrofitting actions, comfort perceptions and building management behaviours. All users are optimistic about the sensor installation process – POLITO has discussed with them about sensor positioning to reduce invasive intervention or to agree on cases in which plugs are needed. Some critical feed backs were collected by a user's relatives and friends, who were scared for their privacy. Still, all users were informed about the sensors allowing them to reduce potential risks.

During the final project year, it will be essential to have a continuous exchange of information with all involved end-users, including residential building owners and tenants (that in our demo case are coincident, like in several Italian houses), school owners (e.g. the Municipality), school managers, teachers, and students. This exchange is considered essential to support the active usage of monitoring data, which will be made available in semi-real time, to support a better energy and comfort use of buildings. Additionally, POLITO is interested in continuously receiving feedback from users to analyse criticalities and positive issues.

3.4 Practical observations

Due to the COVID pandemic situation, school buildings faced in the monitored periods a managing scheme that is not the traditional one. In particular, to respect ministry requirements, almost all windows are left open even in the winter to assure air exchanges and limit infection risks. This affects the CO2 level monitored in the rooms, which is almost more positive than expected by past studies in Italian school buildings, and room temperature and potentially consumption. Nevertheless, during the next studying phase, it may be possible to test via simulations CO2 concentrations under an expected typical behaviour with limited window opening periods in winter.

Focussing on building monitoring issues, sensor costs reveal to be higher than expected. At the same time, the number of available competitors in the local market is still limited, especially when the technical specifications mentioned above are assumed. Nevertheless, with minor budget re-organisation, thanks to a discount, and balancing the installation of CO2 in most representative environmental units, supporting the others with only temperature and temperature and humidity sensors, it has been possible to finalise the original monitoring objectives defined for the Italian demos. Schools, in particular, have a CO2 detector in all most-used rooms (classrooms), excluding a few rooms in which minor or limited activities are expected. Nevertheless, for the municipality school, the intermediated floor of the middle school part has some rooms without CO2 sensors. This general choice allows the implementation of simplification studies by analysing different aggregations of the monitored data (by spaces, by activity, by floor, by building) in parallel to other collections of the simulated data. Results of this study will be included in the following year's report on demo case analyses. Differently, in residential houses, a limited number of CO2 sensors have been installed, focussing mainly on primary spaces, i.e. living spaces and bedrooms. Residential building 3 (B2.5) is characterised to have only one CO2 sensor (kitchen and living) since it only has one occupant, and internal doors are generally all left open. Nevertheless, all main rooms are monitored for temperature, relative humidity, and all spaces with temperature sensors.

Due to some delays connected to COVID pandemic lockdowns and parallel limitations in electronic device availability, heat meter sensors have been installed and activated only in the later winter 2022 season (according to the demo case from the end of February to the beginning of March 2022). Additionally, in the residential demo B2.4 the installation was performed only in the summer of 2022 (July) because the owner defined to change its heating system with a more performative one. Also, thanks to E-DYCE correlated continuous discussions with end-users.

Such as mentioned above, main monitoring actions have been implemented. The delay in collecting heat meter data (energy needs) can be underlined, which limits the possibility of starting energy needs analyses that include monitored data. Nevertheless, an entire heating season will be available starting from September to conclude specific studies for the next reporting phase.

Several difficulties have been underlined in using the data transmitted by window-opening sensors. These sensors are very battery-consuming and the agreed installation approach (not drilling in the wooden frames) causes some separation of parts with a lack of data. Additionally, in cases where the system is continuously working, we have underlined difficulties in interpreting the obtained data. The usage of this information during the elaboration data phase will be hence limited.

Global interest in making buildings more intelligent is underlined. Nevertheless, this is facing a growing market with few solutions allowing to connect data to the cloud and leaving the possibility to interconnect systems and monitoring solutions and having open API access for further analyses and actions. The solutions chosen for monitoring the Italian demos are available on the local market and are generally used to manage public and office building heating systems. This choice may open to easier future diffusion of the proposed approach being demonstrated with solutions compatible with the ones already on the market.

3.5 Monitoring specifications and plans

Adopted monitoring equipment is presented in this chapter. Monitoring infrastructure allow to measure in all the five demo buildings environmental and essential energy data – see also E-DYCE D5.4 for a deeper description of all acquired sensors. Sensors are connected via the cloud to a POLITO server facility and the project middleware to support further analysis and inform end-users.

Sensors and connected data are named according to the suggestion given in E-DYCE D3.2. At the same time, the same nomenclature approach has been followed for the developed building models to match model zones with sensor locations. Similarly, monitored variables follow the suggested nomenclature, e.g. T_db_i[C] for internal dry bulb temperature in Celsius; CO2_i[ppm] for internal CO2 ppm concentration; RH_i[%] for internal relative humidity; Q_h[kWh/m2] or [kWh] for heating needs or Q_c[kWh/m2] for cooling ones.

The following Table 14 reports the main sensor types installed in the demos.

Table 14 Variables and nomenclature.

Dataloggers (variable compositions)	**Name for PRE-DYCE PG scenario**
DBT	T_db_i[C]
DBT+RH%	T_db_i[C] + RH_i[%]
DBT+RH%+CO2	T_db_i[C] + RH_i[%] + CO2_i[ppm]
DBT+RH%+Lux	T_db_i[C] + RH_i[%] + LUX_i[lx]
DBT+RH%+VOCs	T_db_i[C] + RH_i[%] + TVOC_i[ppm]
DBTex+DD	T_db_e[C] + HDD[C]
DBTex+External CO2	T_db_e[C] + CO2_e[ppm]
Electrical consumption (pulse)	Q_l[kWh] or Q_l[Wh]
Heat flow(pulse & suppl.return temp)	Q_h[kWh]
Surface temp.	nd
State (window open)	nd
Additional	
routers	-
Gateways	-

The quantities of dataloggers and sensor types installed per demo are reported in the following Table 15.

Table 15 The quantities of dataloggers installed per demo are reported in the following

Dataloggers (variable compositions)	**B2.1a**	**B2.1b**	**B2.2**	**B2.4**	**B2.3**	**B2.5**
DBT	3	2		3	4	2
DBT+RH%	10	10	6	6	8	3
DBT+RH%+CO2	7	7***	10	4	3	1
DBT+RH%+Lux	1	2				
DBT+RH%+VOCs	1	1				
DBTex+DD	1		1	1		
DBTex+External CO2	1					
Electrical consumption (pulse)	1*		1	1	1	1
Heat flow(pulse & suppl.return temp)	3 (Q_H)		1 (Q_H)	2 (Q_H)	2 (Q_H)	2 (DHW+Q_H)
Surface temp.				1 (2 probes)	1 (2p.)	1 (2p.)
State (window open)	3 (6p.)	6 (12p.)		4 (4p.)		2 (2p.)
Routers	2	2	3	2	1	1
Actuators						
Detached mechanical ventilation (DMV)	3**					

**this electrical sensor read the 3 phases of a larger meter and is included in the main electrical panel of the school.*

***Helty Flow 800 – not connected to the other systems*

****5 sensors installed 20/04/2021, 2 installed 7/03/2022 (refining monitoring)*

Sensors cover almost all rooms and spaces in both schools and residential buildings. Additional probes (e.g. Kamstrup heat meters, external CO2 sensor, electricity meter, and external surface temperature probes) are connected to a Capetti datalogger transmitting via LuPo to the Capetti gateways. Each demo has a gateway that collects all sensors, excluding the municipality school (B2.1), which has two gateways due to the higher number of dataloggers. In the last demo, the first gateway covers the kindergarten and the first, middle school floor, including all energy sensors (both electrical and thermal). The second gateway covers the upper two floors of the middle school. All gateways are positioned in central building space, and battery routers have been set to increase the signal of farther installed sensors.

A plan view for internal uses has been developed for all demos, including sensor localisation and MAC address, to facilitate the connection between sensors and simulation models and support specific analyses. The plan view is detailed in E-DYCE D5.4 and here Figure 9 shows only extract of the monitoring infrastructure in selected demo case.

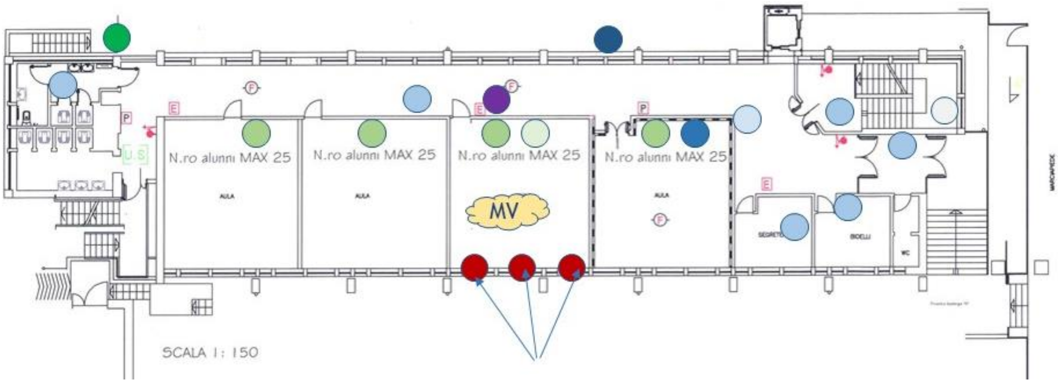


Figure 9 Overview of monitoring infrastructure installed in one of the Italian demonstration cases

The colour legend is based on the following Table 16.

Table 16 Colour legend supporting Figure 9.

color	types	color	types
	DBT		Electrical consumption (pulse)
	DBT+RH%		Heat flow
	DBT+RH%+CO2		DBT+CO2 (external)
	DD		State (window open)
	DBT+RH%+Lux		Gateway
	DBT+RH%+VOCs		Routers

Table 17 gives a general overview of the sensor starting transmission date in demos. Additional information is provided in E-DYCE D5.4. All demos are connected with FusiX while transmitting data to the Polito server and have a cloud service by Capetti and Netsens (meteorological station) providing access to all data monitored during the project.

Table 17 Timeline of installation of monitoring equipment in Italian demonstration buildings.

Demo	First sensor transmitting	Environmental sensor	Electricity sensor	Heat meter	Others
B2.1	20/04/2021	20/04/2021	20/04/21 16/11/21**	02/03/2022	Xx/xx/21 (External CO2); 26/01/22 (DMV)*; 7/03/2022 (extra CO2_i)
B2.2	17/05/2021	17/05/2021	24/11/2021	02/03/2022	
B2.3	08/04/2021	08/04/2021	08/04/2021	Summer 2022**	21/02/2022 (Surface temp.)
B2.4	08/04/2021	08/04/2021	08/04/2021	21/02/2022	21/02/2022(Surface temp.)
B2.5	08/04/2021	08/04/2021	08/04/2021	21/02/2022	05/03/2022 (Surface temp.)
Meteo station	13/04/2021	13/04/2021	-	-	-

** the Helty flow 800 units were installed starting from the 3rd of January 2022. We start operating them by Jan 26th, while in July we have installed, thanks to a MDThesis, a removable RaspberryPi-based remote controller to support E-DYCE analyses of the last year.*
***Installed 15th July 2022, activation will follow before the heating season (expected beginning September)*
****installed 20/04, solved connection problems by 16/11/2021*

Such as shown, more than one year of environmental data is available for all demos while writing this report, allowing to support free-running temperature-based verification procedures and to test them in a second year. Currently, available data on energy needs for heating is minimal, so model verification will be refined for the winter season the following year. Minimal data losses were faced at present, e.g. a CO_2 sensor lost data for about seven days but was further renewed by changing its battery. Similarly, an electricity sensor in one of the residential demos has lost some data due to the substitution of the electrical counter (on which the E-DYCE sensor is mounted to read the led blinks) by the electricity provider company. Such as above mentioned the window opening sensors are not fully working.

Considering the abovementioned variables, it can be possible to compute the following KPIs grouped according to E-DYCE D2.4 families.

- For **energy operation**, from the operational point of view it is expected to analyse the heating uses via flow meters (Q_h). We may also report the total electrical consumptions (Q_l), even if this variable is not expected to be elaborated. Such as underlined before, heat meter data currently does not cover an entire year, so this analysis is expected at the end of the 2022-23 heating season.
- Concerning the **energy signature**, analysis will focus on computing the energy signature 1D and 2D for heating and to compare it with simulated data results. This indicator will be calculated at the end of the 2022-23 heating season.
- Several **comfort/quality** KPIs will be computed based on monitored data, including thermal comfort PMV/PPD and adaptive thermal comfort categories. The operative temperature can also be deducted from the air temperature in line with E-DYCE D3.2 (T_op). We also analyse the distribution of hours into CO_2 level categories and we can compute local heating and cooling degree-days (HDD, CDD) together with internal degree days (CIDH and HIDH).
- Considering the **free-running**, the number of free running hours during the heating season (n_fr_h) can be calculated.

Table 18 presents the possibility to address KPI families in the five Italian demo buildings.

Table 18 Overview of expected operational KPI families being addressed in the Italian demo cases.

Demo case building	KPIs			
	Energy operation	Energy signature	Comfort/quality	Free running
B2.1 school	Yes -heating+el.	Yes -Heating	Yes	Yes - heating
B2.2 high school	Yes -heating+el.	Yes -Heating	Yes	Yes - heating
B2.3 res.1	Yes -heating+el.	Yes -Heating	Yes	Yes - heating
B2.4 res.2	Yes -heating+el.	Yes -Heating	Yes	Yes - heating
B2.5 res.3	Yes –(heating)+el.	(Yes -Heating)	Yes	Yes - heating

All residential demos signed informed consent and a GDPR to allow POLITO data acquisition and treatment supporting different project phases. Concerning the Municipality middle school, TPM supported this action being the Municipality the school building owner. Building owners and keepers have been informed about the project and its objectives, including a simple description of essential monitored variables. Additionally, during a POLITO educational activity involving telecommunication engineering master's degree students, a draft version of an APP has been developed to support end-users in having prior access to their building conditions while the E-DYCE official interface is under development. Thanks to this educational activity, we have increased end-user awareness. Additionally, all people involved in the POLITO's E-DYCE team, including university students, have signed confidentiality, data property, and management agreement.

The end-user leaflet allowing research consent includes the following index of contents:

- General data of data owner, data responsible and local scientific responsible
- Section 1: A description of the study and research aims
- Section 2: A description of how the study will be carried on
- Section 3: Why people are asked to participate
- Section 4: Commitment and withdrawn
- Section 5: Needed steps to participate
- Section 6: What will be asked of participants
- Section 7: Potential risks and annoyances
- Section 8: Potential advantages
- Section 9: Privacy, security and data confidentiality
- Section 10: Personal data
- Section 11: What data arrives after the research
- Section 12: Third parties
- Section 13: Other information
- Signature of the scientific local responsible
- Informed consent signature by the end-user
- Informative about EU data protection to participate in the study – GDPR
- The end-user signature of the GDPR

3.6 Dynamic model simulation for DEPC

All the Italian demo buildings are modelled in EnergyPlus, assuming a multi-zonal geometrical approach and a simple HVAC definition, in line with E-DYCE D3.1 and D3.2 suggestions to be managed via PRE-DYCE. The assumed approach aims to study simple actions to fast-modelling buildings via EnergyPlus, focusing on those IDF components requiring less customised starting conditions. This choice allows testing of main automatic changes via the dynamic energy simulation platform. At the geometrical level, the complexity of organising a multi-zone model is not limited. At the same time, the definition of simple HVAC is chosen to avoid demo-specific choices or customised uncommon lines in the IDF file. Although, energy losses and coefficients of performances will be treated for the Italian demos via the python library adopting the KPIs described in WP3 deliverables. This approach is based on the four-progressive energy-loss-coefficients adopted in the Italian EPC standards (the UNI/TS 11300 family). It is adaptable to current methods used in several other countries. These modelling choices are compatible and complementary with the one proposed by the partners in the other country. For example, in Denmark cases, we may test the possibility of running PRE-DYCE with IDF, including detailed and personalised HVAC definitions.

In addition, the main surrounding obstacles have been included in models to include shading effects.

Focussing on the five-demo building basic models – the one used for data analysis and comparison with monitored data – the following development methodology has been followed:

- Firstly, a model is developed using the DesignBuilder commercial interface to set geometrical shapes and basic information retrieved by the inspection plan.
- Secondly, names in the zones are aligned with sensors and organised to allow an automatic recall of outputs at different aggregation levels during FusiX integration and PRE-DYCE runs.
- Thirdly, the model is exported in IDF v8.9 to be treated and managed via the PRE-DYCE interface. In this phase, the python interface controls simulation model inputs (not geometries) and outputs (including specific KPIs).
- Fourthly, the model is verified concerning monitored data using the calibration signature approach [6] – see also E-DYCE D3.2 – using the semi-automatic PRE-DYCE scenario to variate in coherent intervals of original inputted data. In this phase, model inputs are adapted to inspection-based conditions. The action can be performed at a different level of complexity: mean building level or going in deeper at room level, with the consequent drastically increase in complexity and elaboration time. During this phase, feedback from users and a second inspection plan may be needed to analyse better potential causes of a model performance gap, e.g. geometrical issues and building user behaviours (shading, random ventilation, …). Verifications for the summer free-running mode (air temperature and partially CO_2 in school B2.1) have been performed. They will be refined for energy uses during the next project year when extra data will be available – see E-DYCE D5.4.
- Fifthly, the model is adapted for E-DYCE analyses by inputting via PRE-DYCE Standard (EN 16798-1) and Standard modified data.
- Sixthly, the model is used for data analyses. In this phase, multi-version of the model may be stored to feed different usage scenarios, e.g. Performance Gap, KPIs analyses for DEPC, comfort analyses, parametric sensitivity studies by varying sets of variables.

The phases mentioned above may be partially overlapped. They may be refined several times during the data analysis phase to understand better the impact of specific choices following a feedback process.

Due to its complexity, the model of the Municipality school (B2.1) has been sliced into parts, one for each floor, treating internal slabs as adiabatic surfaces. All sliced models have been verified independently, but envelope and primary input data have been homogenised between them being part of the same building. Nevertheless, a whole school model is also available, although it requires too much computational time (about 30') to perform sensitivity or semi-automatic checks reasonably. For the same municipality school building, geometrical zonal simplification studies have been carried out based on the whole model – to be included in the upgraded version of E-DYCE D3.5 – by progressively merging zones.

Models will run using scheduled ventilation, considering standard ventilation rates, even if, for summer conditions and specific analyses, different solutions are available, including mechanical ventilation for testing the DMV systems in the school (B2.1) and adopting the EnergyPlus ZoneVentilation:WindandStackOpenArea. The latter is an IDF object working with simple ventilation but including wind and stack effects without requiring the more complex airflow network model. The latter is compatible with PRE-DYCE but cannot be fully manageable for sensitivity analyses being model specific. Nevertheless, it will be used in AAU models. The proposed intermediate approach is under validation using the ENEA living lab, and results will be presented in the correlated E-DYCE deliverable.

3.7 DEPC framework integration

All buildings are connected to FusiX, the monitoring system compatible with the same SOAP API. Additionally, also the meteorological station is accessible remotely via REST API. Specific versions of the EnergyPlus models of the five Italian demo buildings are prepared to support the PG scenario and other uses via FusiX. For these reasons, data will be accessible via the E-DYCE app allowing for additional end-user involvement and model-to-monitoring comparison via the dynamic simulation platform.

As above mentioned, the adopted monitoring system has a property cloud solution allowing to store data on their web interface and to download them using different communication approaches, including the Capetti system, a SOAP API, and for the meteorological station a REST API service. Data are shared with the POLITO server and Fusix, supporting PRE-DYCE and Italian demo analyses. The sensor-based interfaces are used for initial and fast checks on monitored data, probe battery levels, and to underline potential issues. In contrast, the project-based interfaces will be used for E-DYCE analyses.

We expect to connect all demo buildings to the E-DYCE, FusiX-based app facility to support end-user information and actions. Additionally, during these months, we have developed, thanks to a POLITO educational action involving students by the last year of the MD in ICT for Smart Society, a mobile android application allowing Italian demo providers to have preliminary access to monitored data. This action has been very welcome by end-users and allows two positive outcomes: i.) collect initial feedback by end-users on E-DYCE-demo-correlated mobile applications; ii.) increase the end-user involvement in project actions to prepare the last year's phase involving demo-building analyses.

Considering the DEPC specifications described in E-DYCE D2.4 the expected coverage of KPIs defined in the mentioned deliverable for the five Italian demo buildings are here described by Table 20-24. In addition to EPC data are considered the DEPC asset standard (DEPC-AS) – based on the adaptation of demo building models to standard EN 16798-1 data –, the DEPC asset adapted to actual (DEPC-AA) level – based on the transformation of the standard conditions to inspection-based ones, partially supported by monitored data post-elaboration, and the DEPC operational (DEPC-O) based on observed data analyses. This description is summarized by the five following tables adopting the proposed DEPC scheme.

Table 19 The colour legend for the Tables 20 - 24.

Indicator acc. to D2.4	Explanation
✓ (black)	Potentially available for some demo buildings, but not for the one in focus
✓ (green)	Potentially available for the specific demo building
✓ (yellow)	Uncertain availability for the specific demo building
✗	Unavailable for all demo buildings

Table 20 The expected coverage of KPIs within DEPC framework integration for the B2.1 (infantry and middle school) demo case.

For tenants							
KPI	Symbol	Assessment schema				Evaluation period	
		EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl			✗	✗	month	year
Final energy need for heating	f_Q_h			✓	✓	week	year
Final energy need for cooling	f_Q_c			✗	✗	week	year
Final energy need for DHW	f_Q_dh			✗	✗	week	year
Final energy need for heating for an average space in the building	f_Q_h_av			✓	✓	week	year
Final energy need for cooling for an average space in the building	f_Q_c_av			✗	✗	week	year
Operative temperature	t_op_i			✓	✓	week	
CO_2 concentration	CO2			✓	✓	week	

Fore certification party/Energy service specialist							
KPI	Symbol	Assessment schema				Evaluation period	
		EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl	✓	✗	✗	✗	month	year
Primary energy need for heating	Q_h	✓	✓	✓	✓	week/month	year
Primary energy need for cooling	Q_c	✗	✓	✓	✗	week/month	year
Primary energy need for DHW	Q_dh	✓	✗	✗	✗	week/month	year
Primary electricity need for running technical installations	Q_tech	✓	✓✗	✓✗	✗	week/month	year
Primary electricity need for lighting (if relevant)	Q_l	✓	✓	✓	✗	week/month	year
Primary energy need for heating for an average space in the building	Q_h_av	✗	✓	✓	✓	week/month	year
Primary energy need for cooling for an average space in the building	Q_c_av	✗	✗	✗	✗	week/month	year
Primary energy need for heating for the critical zone	Q_h_cr	✗	✓	✓	✓	week/month	year
Primary energy need for cooling for the critical zone	Q_c_cr	✗	✗	✗	✗	week/month	year
Energy signature, global solar correlated	EN_SIG_2D		✓	✓	✓	month	year
Energy signature, global solar correlated for the critical zone (heating)	EN_SIG_2D_h		✓	✓	✓	week/month	year
Energy signature, global solar correlated for the critical zone (cooling)	EN_SIG_2D_c		✓	✓	✓	week/month	year
Fictious Energy need for free-running mode (cooling)	FICT_COOL	✗	✓	✓		week/month	year
Fictious Energy need for free-running mode (heating)	FICT_HEAT	✗	✓	✓		week/month	year
Number of free-running hours (cooling season)	n_fr_c	✗	✓	✓	✓	week/month	year
Number of free-running hours (heating season)	n_fr_h	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (cooling season)	n_fr_cr_c	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (heating seson)	n_fr_cr_h	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for heating season	n_co2_h_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for cooling season	n_co2_c_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III, for heating season	n_co2_h_aIII	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I for the zone with maximum heating/cooling demand	n_co2_cr_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III for the zone with minimum heating/cooling demand	n_co2_cr_aIII	✗	✓	✓	✓	week/month	year
Operative temperature in the critical zone for heating season	T_op_cr_h_i		✓	✓	✓	week	year
Operative temperature in the critical zone for cooling season	T_op_cr_c_i		✗	✗	✗	week	year
Operative temperature in the critical zone in free-running for heating			✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for cooling			✓	✓	✓	week	year

Table 21 The expected coverage of KPIs within DEPC framework integration for the B2.2 (high school) demo case.

For tenants							
KPI		Assessment schema				Evaluation period	
	Symbol	EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl			✗	✗	month	year
Final energy need for heating	f_Q_h			✓	✓	week	year
Final energy need for cooling	f_Q_c			✗	✗	week	year
Final energy need for DHW	f_Q_dh			✗	✗	week	year
Final energy need for heating for an average space in the building	f_Q_h_av			✓	✓	week	year
Final energy need for cooling for an average space in the building	f_Q_c_av			✗	✗	week	year
Operative temperature	t_op_i			✓	✓	week	
CO_2 concentration	CO2			✓	✓	week	

Fore certification party/Energy service specialist							
KPI		Assessment schema				Evaluation period	
	Symbol	EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl	✓	✗	✗	✗	month	year
Primary energy need for heating	Q_h	✓	✓	✓	✓	week/month	year
Primary energy need for cooling	Q_c	✗	✗	✗	✗	week/month	year
Primary energy need for DHW	Q_dh	✓	✗	✗	✗	week/month	year
Primary electricity need for running technical installations	Q_tech	✓✗	✓✗	✓✗	✗	week/month	year
Primary electricity need for lighting (if relevant)	Q_l	✓	✓	✓	✗	week/month	year
Primary energy need for heating for an average space in the building	Q_h_av	✗	✓	✓	✓	week/month	year
Primary energy need for cooling for an average space in the building	Q_c_av	✗	✗	✗	✗	week/month	year
Primary energy need for heating for the zone with lowest demand	EP_H	✗	✓	✓	✓	week/month	year
Primary energy need for cooling for the zone with lowest demand	Ep_c	✗	✓	✓	✓	week/month	year
Primary energy need for heating for the critical zone	Q_h_cr	✗	✓	✓	✓	week/month	year
Primary energy need for cooling for the critical zone	Q_c_cr	✗	✗	✗	✗	week/month	year
Energy signature, global solar correlated	EN_SIG_2D		✓	✓	✓	month	year
Energy signature, global solar correlated for the critical zone (heating)	EN_SIG_2D_h		✓	✓	✓	week/month	year
Energy signature, global solar correlated for the critical zone (cooling)	EN_SIG_2D_c		✓	✓	✓	week/month	year
Fictious Energy need for free-running mode (cooling)	FICT_COOL	✗	✓	✓		week/month	year
Fictious Energy need for free-running mode (heating)	FICT_HEAT	✗	✓	✓		week/month	year
Number of free-running hours (cooling season)	n_fr_c	✗	✓	✓	✓	week/month	year
Number of free-running hours (heating season)	n_fr_h	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (cooling season)	n_fr_cr_c	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (heating seson)	n_fr_cr_h	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for heating season	n_co2_h_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for cooling season	n_co2_c_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III, for heating season	n_co2_h_aIII	✗	✓	✓	✓	week/month	year
heating/cooling demand	n_co2_cr_bI	✗	✓	✓	✓	week/month	year
minimum heating/cooling demand	n_co2_cr_aIII	✗	✓	✓	✓	week/month	year
Operative temperature in the critical zone for heating season	T_op_cr_h_i		✓	✓	✓	week	year
Operative temperature in the critical zone for cooling season	T_op_cr_c_i		✗	✗	✗	week	year
Operative temperature in the critical zone in free-running for heating			✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for cooling			✓	✓	✓	week	year

Table 22 The expected coverage of KPIs within DEPC framework integration for the B2.3 (residential 1) demo case

For tenants							
KPI		Assessment schema				Evaluation period	
	Symbol	EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl	✓		✗	✗	month	year
Final energy need for heating	f_Q_h	✓		✓	✓	week	year
Final energy need for cooling	f_Q_c	✗		✗	✗	week	year
Final energy need for DHW	f_Q_dh	✓		✗	✗	week	year
Final energy need for heating for an average space in the building	f_Q_h_av			✓	✓	week	year
Final energy need for cooling for an average space in the building	f_Q_c_av			✗	✗	week	year
Operative temperature	t_op_i			✓	✓	week	
CO_2 concentration	CO2			✓	✓	week	

Fore certification party/Energy service specialist							
KPI		Assessment schema				Evaluation period	
	Symbol	EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl	✓	✗	✗	✗	month	year
Primary energy need for heating	Q_h	✓	✓	✓	✓	week/month	year
Primary energy need for cooling	Q_c	✗	✗	✗	✗	week/month	year
Primary energy need for DHW	Q_dh	✓	(✓)	(✓)	✗	week/month	year
Primary electricity need for running technical installations	Q_tech	✗	✗	✗	✗	week/month	year
Primary electricity need for lighting (if relevant)	Q_l	✗	✗	✗	✗	week/month	year
Primary energy need for heating for an average space in the building	Q_h_av	✗	✓	✓	✓	week/month	year
Primary energy need for cooling for an average space in the building	Q_c_av	✗	✗	✗	✗	week/month	year
Primary energy need for heating for the critical zone	Q_h_cr	✗	✓	✓	✓	week/month	year
Primary energy need for cooling for the critical zone	Q_c_cr	✗	✗	✗	✗	week/month	year
Energy signature, global solar correlated	EN_SIG_2D		✓	✓	✓	month	year
Energy signature, global solar correlated for the critical zone (heating)	EN_SIG_2D_h		✓	✓	✓	week/month	year
Energy signature, global solar correlated for the critical zone (cooling)	EN_SIG_2D_c		✗	✗	✗	week/month	year
Fictious Energy need for free-running mode (cooling)	FICT_COOL	✗	✓	✓		week/month	year
Fictious Energy need for free-running mode (heating)	FICT_HEAT	✗	✓	✓		week/month	year
Number of free-running hours (cooling season)	n_fr_c	✗	✓	✓	✓	week/month	year
Number of free-running hours (heating season)	n_fr_h	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (cooling season)	n_fr_cr_c	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (heating seson)	n_fr_cr_h	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for heating season	n_co2_h_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for cooling season	n_co2_c_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III, for heating season	n_co2_h_aIII	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I for the zone with maximum heating/cooling demand	n_co2_cr_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III for the zone with minimum heating/cooling demand	n_co2_cr_aIII	✗	✓	✓	✓	week/month	year
Operative temperature in the critical zone for heating season	T_op_cr_h_i		✓	✓	✓	week	year
Operative temperature in the critical zone for cooling season	T_op_cr_c_i		✗	✗	✗	week	year
Operative temperature in the critical zone in free-running for heating			✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for cooling			✓	✓	✓	week	year

Table 23 The expected coverage of KPIs within DEPC framework integration for the B2.4 (residential 2) demo case.

For tenants							
KPI		Assessment schema				Evaluation period	
	Symbol	EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl	✓		✗	✗	month	year
Final energy need for heating	f_Q_h	✓		✓	✓	week	year
Final energy need for cooling	f_Q_c		✓	✓		week	year
Final energy need for DHW	f_Q_dh	✓				week	year
Final energy need for heating for an average space in the building	f_Q_h_av			✓	✓	week	year
Final energy need for cooling for an average space in the building	f_Q_c_av			✗	✗	week	year
Operative temperature	t_op_i			✓	✓	week	
CO_2 concentration	CO2			✓	✓	week	

Fore certification party/Energy service specialist							
KPI		Assessment schema				Evaluation period	
	Symbol	EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl	✓	✗	✗	✗	month	year
Primary energy need for heating	Q_h	✓	✓	✓	✓	week/month	year
Primary energy need for cooling	Q_c	✗	✗	✗	✗	week/month	year
Primary energy need for DHW	Q_dh	✓	✓✗	✓✗	✓✗	week/month	year
Primary electricity need for running technical installations	Q_tech	✗	✗	✗	✗	week/month	year
Primary electricity need for lighting (if relevant)	Q_l	✗	✗	✗	✗	week/month	year
Primary energy need for heating for an average space in the building	Q_h_av	✗	✓	✓	✓	week/month	year
Primary energy need for cooling for an average space in the building	Q_c_av	✗	✗	✗	✗	week/month	year
Primary energy need for heating for the critical zone	Q_h_cr	✗	✓	✓	✓	week/month	year
Primary energy need for cooling for the critical zone	Q_c_cr	✗	✗	✗	✗	week/month	year
Energy signature, global solar correlated	EN_SIG_2D		✓	✓	✓	month	year
Energy signature, global solar correlated for the critical zone (heating)	EN_SIG_2D_h		✓	✓	✓	week/month	year
Energy signature, global solar correlated for the critical zone (cooling)	EN_SIG_2D_c		✗	✗	✗	week/month	year
Fictious Energy need for free-running mode (cooling)	FICT_COOL	✗	✓	✓		week/month	year
Fictious Energy need for free-running mode (heating)	FICT_HEAT	✗	✓	✓		week/month	year
Number of free-running hours (cooling season)	n_fr_c	✗	✓	✓	✓	week/month	year
Number of free-running hours (heating season)	n_fr_h	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (cooling season)	n_fr_cr_c	✗	✓	✓	✓	week/month	year
Number of free-running hours for critical room (heating seson)	n_fr_cr_h	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for heating season	n_co2_h_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for cooling season	n_co2_c_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III, for heating season	n_co2_h_aIII	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I for the zone with maximum heating/cooling demand	n_co2_cr_bI	✗	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III for the zone with minimum heating/cooling demand	n_co2_cr_aIII	✗	✓	✓	✓	week/month	year
Operative temperature in the critical zone for heating season	T_op_cr_h_i		✓	✓	✓	week	year
Operative temperature in the critical zone for cooling season	T_op_cr_c_i		✗	✗	✗	week	year
Operative temperature in the critical zone in free-running for heating			✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for cooling			✓	✓	✓	week	year

Table 24 The expected coverage of KPIs within DEPC framework integration for the B2.5 (residential 3) demo case.

For tenants							
KPI	Symbol	Assessment schema				Evaluation period	
		EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl	✓		×	×	month	year
Final energy need for heating	f_Q_h	✓		✓	✓	week	year
Final energy need for cooling	f_Q_c	×		×	×	week	year
Final energy need for DHW	f_Q_dh	✓		✓	✓	week	year
Final energy need for heating for an average space in the building	f_Q_h_av			✓	✓	week	year
Final energy need for cooling for an average space in the building	f_Q_c_av			×	×	week	year
Operative temperature	t_op_i			✓	✓	week	
CO_2 concentration	CO2			✓	✓	week	

Fore certification party/Energy service specialist							
KPI	Symbol	Assessment schema				Evaluation period	
		EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max
Global energy performance index	Q_gl	✓	×	×	×	month	year
Primary energy need for heating	Q_h	✓	✓	✓	✓	week/month	year
Primary energy need for cooling	Q_c	×	×	×	×	week/month	year
Primary energy need for DHW	Q_dh	✓	✓	✓	✓	week/month	year
Primary electricity need for running technical installations	Q_tech	×	×	×	×	week/month	year
Primary electricity need for lighting (if relevant)	Q_l	×	×	×	×	week/month	year
Primary energy need for heating for an average space in the building	Q_h_av	×	✓	✓	✓	week/month	year
Primary energy need for cooling for an average space in the building	Q_c_av	×	×	×	×	week/month	year
Primary energy need for heating for the critical zone	Q_h_cr	×	✓	✓	✓	week/month	year
Primary energy need for cooling for the critical zone	Q_c_cr	×	×	×	×	week/month	year
Energy signature, global solar correlated	EN_SIG_2D		✓	✓	✓	month	year
Energy signature, global solar correlated for the critical zone (heating)	EN_SIG_2D_h		✓	✓	✓	week/month	year
Energy signature, global solar correlated for the critical zone (cooling)	EN_SIG_2D_c		×	×	×	week/month	year
Fictious Energy need for free-running mode (cooling)	FICT_COOL	×	✓	✓		week/month	year
Fictious Energy need for free-running mode (heating)	FICT_HEAT	×	✓	✓		week/month	year
Number of free-running hours (cooling season)	n_fr_c	×	✓	✓	✓	week/month	year
Number of free-running hours (heating season)	n_fr_h	×	✓	✓	✓	week/month	year
Number of free-running hours for critical room (cooling season)	n_fr_cr_c	×	✓	✓	✓	week/month	year
Number of free-running hours for critical room (heating seson)	n_fr_cr_h	×	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for heating season	n_co2_h_bI	×	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I, for cooling season	n_co2_c_bI	×	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III, for heating season	n_co2_h_aIII	×	✓	✓	✓	week/month	year
Number of hours when CO2 level is below category I for the zone with maximum heating/cooling demand	n_co2_cr_bI	×	✓	✓	✓	week/month	year
Number of hours when CO2 level is above category III for the zone with minimum heating/cooling demand	n_co2_cr_aIII	×	✓	✓	✓	week/month	year
Operative temperature in the critical zone for heating season	T_op_cr_h_i		✓	✓	✓	week	year
Operative temperature in the critical zone for cooling season	T_op_cr_c_i		×	×	×	week	year
Operative temperature in the critical zone in free-running for heating			✓	✓	✓	week	year
Operative temperature in the critical zone in free-running for cooling			✓	✓	✓	week	year

4 Demonstration case 4 – Multi apartment buildings, Aalborg and Frederikshavn, Denmark

4.1 Description of the demonstration cases

Pilot cases selected for E-DYCE demonstration in Denmark represent building typology of residential multiapartment blocks that are typical for construction erected between 1961 and 1980 year. During these years, construction activities were blooming in Denmark and resulted in building homes that nowadays constitute a very significant share of Danish residential stock, approximately 23,5%, of this building lump type are often very well located in cities and require energy renovation. While originally these buildings usually fall into EPC label E-F (respectively total primary energy demand of 170 -240 kWh/m2) majority of them has gone through some-kind of renovation resulting in improvement of energy label that would fall after renovation into class C – D (respectively 100 – 130 kWh/m2). Approximately 80% of total energy use in these buildings is used for heating (space heating and domestic hot water production). Short overview of the Danish pilot buildings is presented in Figure 10 with indicated year of construction, heated floor area, installation of PreHEAT (Neogrid's predictive weather compensation to optimize space heating and domestic hot water production), existing energy and indoor climate metering infrastructure (that is in more in detail specified in E-DYCE D5.5), availability of energy label at beginning of E-DYCE project. In this report building B4.1 is called "Haandbaek", B4.2 is called "Magisterparken" and B4.3 is called "Thulevej". All three building sites are administrated, maintained, and managed by three different housing associations which means all apartments are for rent and occupied by tenants (not owned by tenants).

1	2	3
Multi apartment residential – Hånbæk Fredrikshavn	Multi apartment residential – Magisterparken Aalborg	Multi apartment residential – Thulevej Aalborg
		
Built: 1972 (renovation in 2011)	**Built**: 1964 (renovation in 2012)	**Built**: 1969 (renovation in 2010)
Heated area: 4756m^2 (44 apartments)	**Heated area**: 2398 (12 apartments)	**Heated area**: 3262 (39 apartments)
PreHEAT start date October 2017	**PreHEAT** start date July 2017	**PreHEAT** start October 2017
Data available - Building level: Main energy meters, resolution: 1min Energy domestic hot water, resolution: 1min Energy space heating meter, resolution: 1min **Data available - Apartment level:** CHW volume consumption, resolution: h Energy space heating meter, resolution: h T and humidity, resolution: 5min • building history[35], Section includes several similar buildings	**Data available - Building level:** Main energy meters, resolution: h Energy domestic hot water, resolution: 1min **Data available - Apartment level:** T and humidity, resolution: 5min • 4 identical buildings	**Data available - Building level:** Main energy meters, resolution: h Energy DHW, resolution: 1min **Data available - Apartment level:** T and humidity, resolution: 5min • 4 identical buildings

Figure 10 Danish pilot buildings participating in E-DYCE monitoring

All three pilot cases are located in region of North Jutland in Denmark. One case building is placed in city of Frederikshavn and two in Aalborg. Their locations are presented in Figure 11.

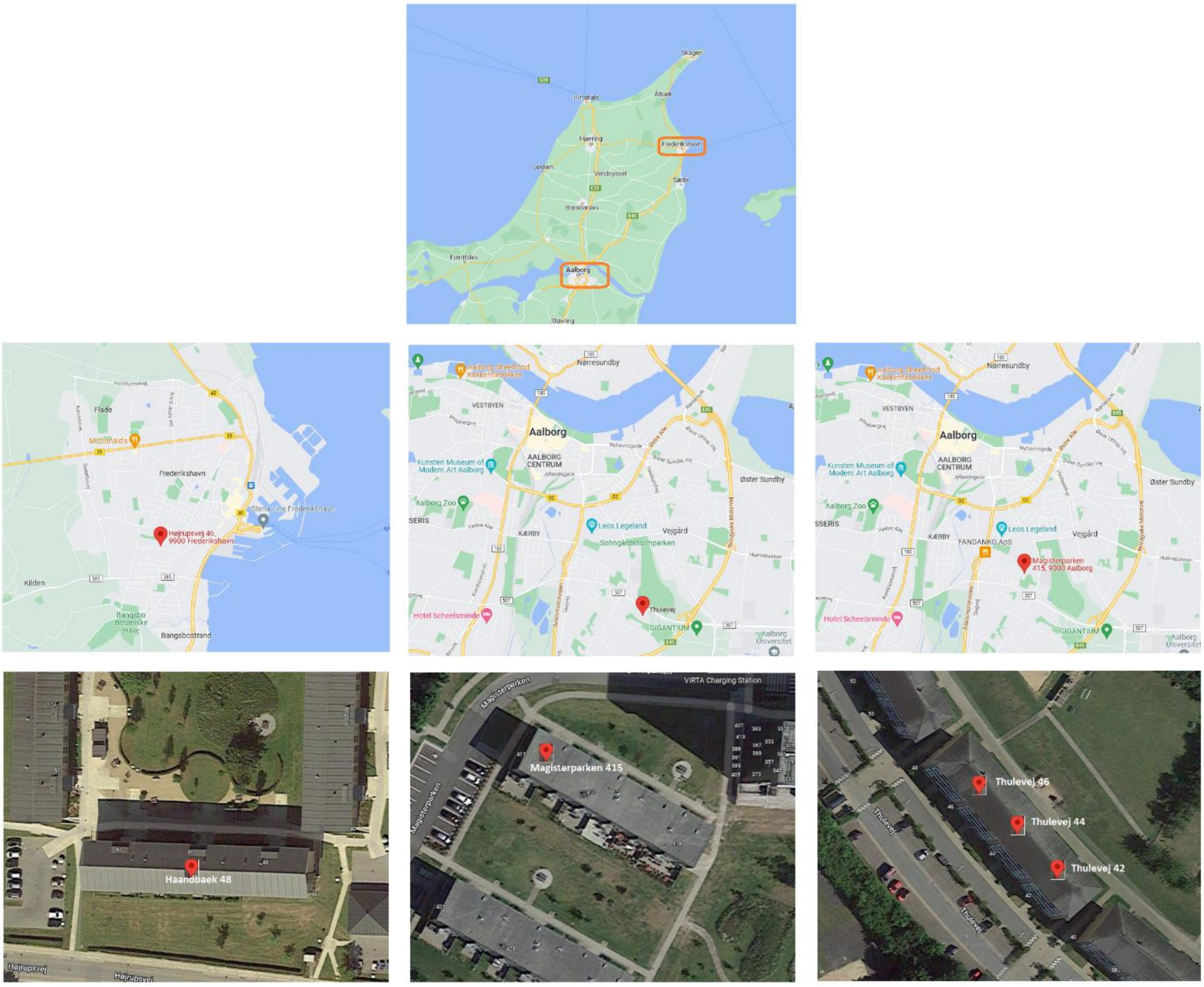


Figure 11 Location of building Haandbaek (Fredrikshavn), Magisterparken (Aalborg) and Thulevej (Aalborg

The detailed properties of building envelope elements, transmittance properties of the opaque envelope elements and windows properties are provided in D5.5. Moreover, for one case building this information have been as well presented in inspection protocol linked to this report. The most detailed information regarding envelope composition, material properties and thickness together with section drawings can be found in Appendix to E-DYCE D5.5. Detailed composition of building envelope is required to develop dynamic models of the pilot cases.

To be able to reflect on both energy use and indoor climate, energy metering and indoor climate measuring devices were planned to be installed from the beginning of the project. The motivation for these measurements is twofold. First, indoor climate parameters, for example, temperatures are measured in order to compare them with simulated one for the purpose to detect reasons for performance gap. Second, the same measurements are to be used to correct assumptions regarding condition of use of the buildings. For example, standard indoor temperature is expected to be corrected to actual and used for development of "adapted" modelling condition. Regarding energy monitoring, here motivation is focused on space heating and where possible energy use for DHW. Due to the complexity and technical challenges related to installation of heat meters on hydraulic circuits, E-DYCE has decided to rely on the existing infrastructure for heat measurements and only clamp on temperature sensors have been installed on the pipes to detect on radiators activation and to support disaggregation of energy for DHW.

To sum up, the instrumentation and analysis of Danish pilots is focused on:

- Firstly, dominant energy use – that is space heating and where possible domestic hot water (Haanbaek pilot).

- Secondly, indoor climate and parameters that might in significant manner influence heat use, for example, window opening activities, air change rates from direct and indirect (CO2) measurements (Haanbaek, Magisterparken, Thulevej).

Regarding end user requirements, these are not specified for the three selected buildings by the administrators of the buildings. However, since buildings are operated by building associations that continuously renovate and energy optimize their building portfolio, E-DYCE objectives align. These alignments are: detection of reasons behind performance gap, credible energy renovation plans, improvement of indoor environment or consequences of renovation on indoor environment, consequently improvement of classical energy label of buildings.

The analysis that E-DYCE can offer by its DEPC is expected to vary for the three Danish pilot buildings and depends on the monitoring coverage (number of apartments participating it the monitoring campaign), number and type of deployed sensors, pre-existing energy monitoring infrastructure and level of modelling detail (mostly with regards to zoning). In Haanbaek availability of data allows for energy (space heating and DHW) and indoor climate assessment whereas Magisterparken and Thulevej allow for primary indoor climate assessment. Another significant difference in approach between Haanbaek and respectively Magisterparken and Thulevej is that in Haanbaek it was possible to collect significantly more detailed information on the building and its actual use. For instance, monitoring equipment is able to log information about:

- The space heat use at apartment level (potentially also heat for DHW use that is very seldom to know),

- The indoor climate parameters are monitored down to room level (temperature in all rooms and RH and CO2 in selected rooms),

- information about building thermal characteristic from both conducted standard EPC labelling and available good technical documentation about the building, interviews with tenants that capture information about actual people loads, preferred temperatures, venting routines, satisfaction with current indoor climate, presence and use of solar shading devices.

In contrary in Magisterparken and Thulevej, several types of information are not available as for Haanbaek, which reflect more realistic level of availability of information in assessed buildings. The primary difference is that space heat use is available only at building level and not apartment level, the installed monitoring allows for indoor climate monitoring though and only in few spaces. Compliance calculation to determine buildings labels has been conducted internally by AAU and not ordered to independent EPC evaluator. Interviews with tenants have been disregarded.

Taking into account different level of information in pilot cases the deployment of DEPC evaluation reaches to various depths and should reflect on flexibility of the developed approach. The overview of expected possible implementation of DEPC in Danish demonstration cases is provided in section 5.7 in this report.

4.1.1 Inspection protocols

The standard approach and objective of use of inspection protocol is to support the user of the E-DYCE method to build the three simulation models (EPC standard, DEPC standard, DEPC actual) and to finally identify the reasons for the performance gap. The building inspection protocol sheets contains all/majority of the necessary information for the calculation of a standard EPC, as all the envelope's elements are listed. In addition, several sheets contain dynamic parameters that either must be filled by the inspector or read from the EU standard. This allows all four calculations to be performed with one inspection sheet.

Since EPC models of the Danish pilot buildings have been developed prior the inspection protocol were ready the exercise for the Danish case is to identify convergence between current Danish inputs collected either in EPC labels or in compliance models (these two are compatible) and E-DYCE inspection protocol.

The first step of use of inspection protocol is to identify static inputs. Another unique feature of DEPC inspection protocol is the "Zone dynamic" that allows for collecting and comparing standard dynamic settings both national and international (set points and loads) with actual observations in order to create standard asset DEPC models and adapted DEPC models.

The detailed finding and recommendations are provided in D5.5 and are based on the model of Haanbaek pilot case. The protocol is collected in Excel format and can be accessed from E-DYCE web page.

The filled inspection protocol can be accessed here:

https://E-DYCE.eu/e-dyce-inspection-protocol-denmark/

4.2 Static EPCs

Static models of Haanbaek, Magisterparken and Thulevej have been developed using Danish national compliance tool Be18. The key results from the models are presented in this section in Table 25.

Models of Hånbæek and Thulevej have been calculated by automatic import of EPC label in XML format to Be18 compliance tool. Magisterparken had no EPC label available and therefore has been manually input in the Be18 compliance tool.

Danish EPC rates buildings with respect to energy efficiency scale, which ranges from A (high-energy efficiency) to G (low-energy efficiency), see Figure 12. Moreover, class A is divided into three sub-categories A2020, A2018, A2010 reflecting ongoing progress of energy efficiency in BR updates since 2006 until the present. More complete description of Danish EPCs and energy services that are included in the label can be found in E-DYCE D1.1.

EPC rating	Criteria for each class [kWh/m²year]	
	Residential	Non-residential
A2020	20	25
A2015	≤30.0+1,000/A	≤41+1,000/A
A2010	≤52.5+1,650/A	≤71.3+1,650/A
B	≤70.0+2,200/A	≤95+2,200/A
C	≤110+3,200/A	≤135+3,200/A
D	≤150+4,200/A	≤175+4,200/A
E	≤190+5,200/A	≤215+5,200/A
F	≤240+6,500/A	≤265+6,500/A
G	>240+6.500/A	>265+6.500/A

Figure 12 Danish EPC label ranges.

All three Danish demonstration cases have been assessed with respect to their global energy performance index and with respect to primary energy need for: heating, cooling, domestic hot water, electricity for building operation and lighting common areas. Energy for electricity need for lighting in the occupied spaces (apartments) is excluded as prescribed in Danish Building Regulations. Calculated results and obtained EPC labels are given in Table 25.

Table 25 EPC results for the Danish case studies (all energies given in primary energy).

KPI	[Unit]	Hånbæk	Magisterparken	Thulevej
Global energy performance index	[kWh/m2 year]	70,0	104,2	69,1
Primary energy need for heating	[kWh/m2 year]	45,7	73,5	51,0
Primary energy need for cooling (overheating penalty)	[kWh/m2 year]	0,0	23,0	0
Primary energy need for DHW	[kWh/m2 year]	14,6	17,4	17,6
Primary electricity need for running technical installations	[kWh/m2 year]	9,7	1,0	0,8
Primary electricity need for lighting (if relevant)	[kWh/m2 year]	0,0	0,0	0,0
EPC label	[#]	B	C	B

4.3 End -user (tenants) feedback

End user feedback refers here to feedback obtained from tenants that occupy apartments that agreed to participate in E-DYCE monitoring campaign. Interviews with end users have been conducted in Haanbaek pilot case. It can be concluded that interviews can provide valuable insight in to operation, loads in the assessed apartments and level of satisfaction about indoor environment. However, collected information can be still difficult to translate into adapted condition for modelling purposes. Part of the interview focused as well on how tenants perceived installation of monitoring equipment in their apartments. In general feedback was positive and no complains have been registered. Here presented some of the conclusions from interview.

- For most of the time apartments are occupied but exact location of occupant in the apartments remain unknown. Provided people load can be used to change standard loads to adapted.

- Occupants are satisfied about air quality.

- All occupants declare to vent their apartments rather often and being conscious with what purpose. The task of mimicking opening windows and scheduling it in the models still seems challenging. Still based on interviews elevated air change rates thanks to natural ventilation especially summer should be considered to better reflect user behaviour and interaction with openable windows. Motivation for opening window is primary fresh air and removal of moisture and when experiencing elevated indoor temperatures. The setting of natural ventilation activation in models remains at expert to decide.

- Occupants are rather satisfied about thermal comfort. Some report signs of elevated temperature and drought from windows, however, no major problems.

- Occupants although are satisfied with thermal comfort in majority are not able to explicitly answer about maintained indoor temperature.

- Setting on radiators can be expected different. Lower settings are in general reported in bedrooms.

- Except one apartment, there is no clear indication if temperature within each apartment is uniform.

- All tenants that agreed to host E-DYCE answer that they positively experienced installation of indoor sensors.

- When asked about spending on energy, tenants indicate that either not much or a little too much is spent. This is also reflected in their rather low motivation to save energy where they declare rather low flexibility for change, and if, they would need to know more explicitly what to change.

The detailed information that has been collected during individual interviews are presented in D5.5.

4.4 Practical observation

Establishing the demonstrators in Denmark has resulted in many learnings in the context of dynamic performance evaluation in the multi-family residential sector.

First, no significant issue was met in accessing the buildings and contacting the building managers. This was however expected given that Neogrid was already providing some services to those buildings prior to the start of the project and had gotten the housing associations owning them to agree to support the project by making them available to it. At building level, there was a clear interest in finding ways of improving operational performance, which aligned well with E-DYCE's purpose.

Second, the main challenge has been to get access to apartments, as engagement with tenants proved significantly more difficult than expected. Getting in contact with the tenants was difficult, as they were often not home when we were physically present on site. Information via flyers in their mailbox did not prove successful either. In future demonstrations within the multi-family residential sector, a stronger focus on this strategy will therefore need to be made.

Third, reuse of existing data collection at apartment level has proved impossible, as no consent to use this data (covered by GDPR due to its household-level resolution) had been obtained to use it for research purposes in the E-DYCE project where it would be shared with third parties. And given the relatively small number of apartments covered by demonstration buildings and the needs of the project to have geographical information about the sensor placement, anonymisation of the data was not an acceptable option.

Lastly, connecting legacy equipment to our data collection has been harder than expected for specific systems that were not connected to the BMS or having a standard digital interface (e.g. Modbus and Bacnet). In particular, in the Haanbaek demonstrator, we did not manage to fruitfully establish a data collection from the legacy ventilation system's controller, despite investing in an expensive protocol adapter (LON to Bacnet) both because of technological challenges and missing technical documentation from the installer.

4.5 Monitoring specification and plans

Monitoring of indoor environment and/or energy is conducted in 4 apartments in Haandbaek, 4 apartments in Thulevej and 2 apartments in Magisterparken. Following naming structure provides apartments being monitored: Location/building number/floor/tv (to the left) or th (the to the right).

Apartments participating in the measuring campaign:

- Haandbaek: 48/0/tv), (48/1/tv), (48/1/th), (48/2/tv)
- Thulevej: (42/4/tv), (44/1/th), (44/2/tv), (44/3/tv)
- Magisterparken: (415/1,tv), (415/2/tv)

Figure 13 presents example apartment per each demonstration case with indication of the sensors and meters being installed. The remaining apartments in each demonstration case are equipped to the same level of sensors as presented in Figure 13. All sensors are connected to Neogrid App and FusiX. Detailed description of measuring equipment specification that has been installed can be found in E-DYCE D5.5.

Haanbaek demonstration case is the only that can offer space heating measurements and information about domestic hot water flows. Additionally, in Haanbaek have been installed temperature sensors on domestic hot water installation (both hot water supply and cold water to heat exchanger) that are not presented in Figure 13. These temperature sensors together with flow meters should allow to provide energy for domestic hot water at apartment level. Haanbaek can offer as well monitoring results for indoor environment. Thermal environment is monitored in each room and air quality (CO2) is monitored in leaving room and master bedroom. Moreover, Haanbaek can offer to monitor users interaction with windows (for natural ventilation). Windows state, closed or open, can be monitored on all windows in all monitored apartment. Finally, 1-wire sensors can be use to monitor supply and return temperature to each radiator.

For the Magisterparken and Thulevej monitoring focuses on indoor environment. Thermal environment is monitored in all rooms in both locations. Moreover, both locations can offer to monitor users interaction with windows (for natural ventilation). Windows state, closed or open, can be monitored on all windows in Thulevej in all monitored apartments. In Magisterparken situation is similar with one small exception that state of two windows in each apartment is not monitored.

It should be also highlighted that in Haanbaek and Magisterparken all monitored apartments belong to one staircase while in Thulevej apartments belong to 3 neighbouring staircases. The reason for that is it was difficult to find volunteers among tenants to provide access to their apartments. This creates additional challenges with respect to collection and sending the data from the buildings both with regards to additional costs (additional gateways) and also data quality (higher probability for data with gaps/missing values).

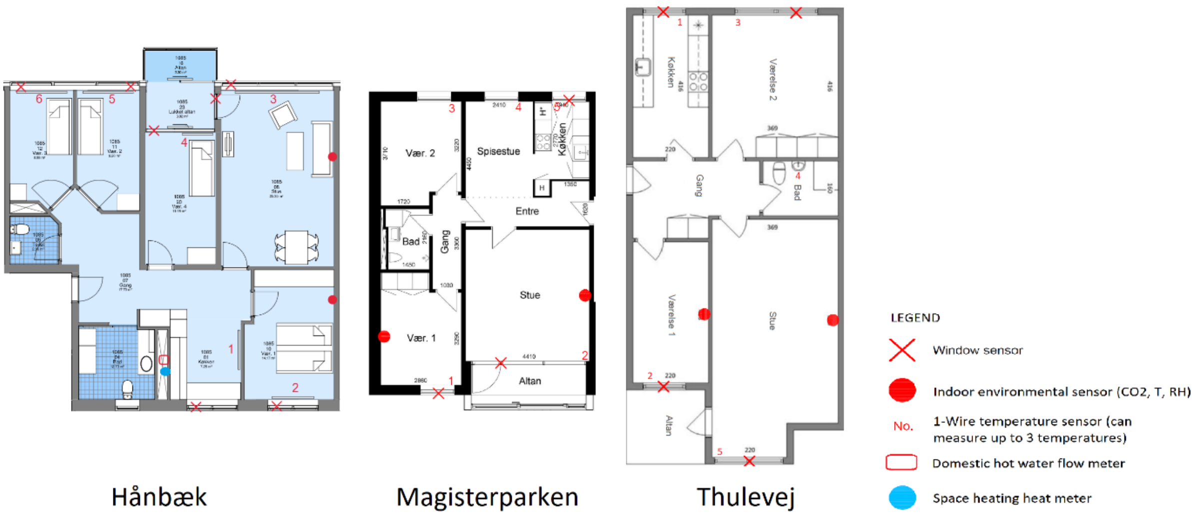


Figure 13 Overview of monitoring equipment that has been installed in Danish demonstration buildings - example at apartment level for each location.

The quantities of applied sensors per location are provided in Table 26 in this report while detailed information about sensors location in each apartment, their specification, gateway solution and locations are provided in E-DYCE D5.5.

Table 26 Overview of sensors and meters installed in Danish demonstration cases.

Sensor type	Haanbaek	Magisterparken	Thulevej
1 -wire (for indoor temperature and humidity)	9	1	2
1-wire (for common pipe measurements)	0	2	0
1-wire (for radiator measurements)	18	1	12
Indoor environmental sensor (T, CO_2, RH)	8	4	8
Window sensor (open/closed)	25	8	17
Domestic hot water flow meter (apartment level)	4	0	0
Space heating meter (apartment level)	4	0	0

Due to the hesitance from tenants and long process to secure signing informed consents the process of deployment of sensors was extended in time. The monitoring in the Danish 3 locations have started as follows:

- Haanbaek: first sensors installed in 12/08/2021
- Magisterparken: first sensor installed in 25/10/2021
- Thulevej: first sensor installed in 08/09/2021

After sensors were installed they were connected to Neogrid App and from there later to FusiX. Details of the Neogrid and FusiX connectivity are presented in E-DYCE D5.5.

The operational KPIs that can be derived in demonstration cases depend on sensors being installed in the buildings and parameters being measured. E-DYCE assessment results were presented in D2.4 (DEPC protocol) and grouped into the following main families. These families are:

- ***Energy operation KPIs*** -more specifically the energy needs in the building, to support identification of the performance gap.
- ***The energy signature KPIs*** -to ease the evaluation of the performance gap of a building/zone due to the operational thermal conditions.
- ***Comfort/quality KPIs*** – to support detection of causes for the performance gap.
- ***Free-running operation* KPIs** – to address issues in certification of low-tech buildings, but also to support passive strategies application in buildings.

The overview of the expected KPI families coverage is presented in Table 27. The scope of the KPI families depends on available monitoring infrastructure in each demonstration building. Based on this overview it can be concluded that Haanbaek demonstration case allows for the most holistic analysis that cover to some extend all four KPI families. Magisterparken and Thulevej demonstration cases are very similar to each other and both allow to perform assessment with regards to comfort/quality and free running operation with respect to heating. More detailed overview of coverage of specific KPIs both operational and asset are presented in section 5.7(DEPC framework integration) in this report.

Table 27 Overview of expected operational KPI families being addressed in the Danish demo cases.

Demo case building	KPIs			
	Energy operation	Energy signature	Comfort/quality	Free running
Haanbaek	Yes -heating	Yes -Heating & DHW	Yes	Yes - heating
Magisterparken	No	No	Yes	Yes - heating
Thulevej	No	No	Yes	Yes - heating

Tenants of all apartments participating in E-DYCE monitoring campaign have been first informed about project, its motivation and objectives by use of the brochure that was specially prepared for tenants. Then after tenants were asked to sign informed consent. Brochure and informed consent are presented in Figure 14. Both brochure and informed consent have been prepared in Danish in order to secure that tenants consciously sign agreement.

Figure 14 Brochure for tenants informing about E-DYCE project (left), informed consent (right)

4.6 *Dynamic model simulation for DEPC*

Considerations for modeling three of the Danish demonstration cases is presented in Table 28 in this chapter. For each of the demonstration cases is presented selected approach for model geometry, how heating/ventilation system is modelled and short comment to each and motivation for the approach. Further on, Håndbæk and Magisterparken models (model A and B, as indicated in Table 28) are shortly elaborated. More detailed model presentation is given in E-DYCE D5.5. Motivation for approach for model of Thulevej is similar to Haanbaek, however, with the exception that the model zoning approach is as in Magisterparken. Thulevej model is to be developed at later stage as first correctness and operability of Haanbaek and Magisterparken are to be proven with PRE-DYCE and FusiX. Motivation for this approach is to reduce resource spending for debugging models and use lessons learned on the first two demo cases. The main difference between Haanbaek, Magisterparken and Thulevej, that require attention, is fact that Haanbaek is mechanically ventilated using balanced ventilation system and offering heat recovery while Magisterparken and Thulevej are naturally ventilated with simple exhaust fans located in bathroom and kitchen.

Moreover, the internal loads are equal for all developed models. Only appliances and occupants were considered. For asset models the operation time, occupancy density and appliance density were based on DS/EN 16798-1, 2019.

Table 28 Overview of dynamic models for DEPC

Demo name	Model geometry	Heating system	Ventilation system	Comment to systems	Motivation
Haanbaek	**A.one room as a zone** B.one zone per staircase	**A. district heating+ water radiator** B. ideal loads	**A. balanced ventilation system (supply and return fan, airflow network) and heat recovery** **B. the same as A**	The ventilation system is balanced ventilation with heat recovery. The ventilator is Exhausto BESB 315 MGE. It is noted in one of the reports that if the inlet temperature drops below 18 deg, then the supply airflow rate is reduced. The heating system is district heating with water radiators.	Case A. is to illustrate the added value of detailed monitoring – we address not only the owner of the building but also a tenant Case B. to illustrate the difference against case A
Magisterparken	**A. one apartment as 1 zone** B. one zone per staircase	**A**. Ideal loads, district heating energy demand B. Ideal loads, district heating energy demand *Both are the same, as we have limited data on this building*	**A.** Airflow network, exhaust ventilation, air intake is covered by defining the size and location of leakages and wind pressure on each external surface. B. Zone ventilation, not considering wind speed and wind direction	The ventilation system consists of exhaust fans in the kitchen and bathroom. The inlet air is going through building cracks and window/door openings.	The building has very few monitoring points, thus it can be focused on simulation/monitoring at the apartment level. In such a case operational DEPC can only include comfort. To address the energy it can only be elaborated on the deviation between the average heating demand per apartment against those that are monitored (simulated).
Thulevej	A. one apartment as 1 zone B. one zone per staircase	A. HighTemperature Radiant component where it can be specified the convective/radiative share. B. Ideal loads, district heating energy demand	A. Zone ventilation, not considering wind speed and wind direction B. Airflow network, exhaust ventilation, air intake is covered by defining the size and location of leakages and wind pressure on each external surface.	To be checked: exhaust fans in the kitchen and bathroom. The inlet air is going through building cracks and window/door openings.	Same as Haanbaek

4.7 DEPC framework integration

The Danish demonstrator's communication structure is built upon Neogrid's PreHEAT cloud solution, which is interfaced further to the FusiX platform for the purpose of the project, see Figure 15. The PreHEAT cloud gathers data from the building's systems via a local gateway interacting with the building systems via BMS (Modbus and Bacnet) and IoT (wireless Mbus) protocols, which forwards measurements via an encrypted MQTT connection. Relevant measurements for the E-DYCE platform are then regularly exported by the PreHEAT cloud to the FusiX platform via a secure FTP connection.

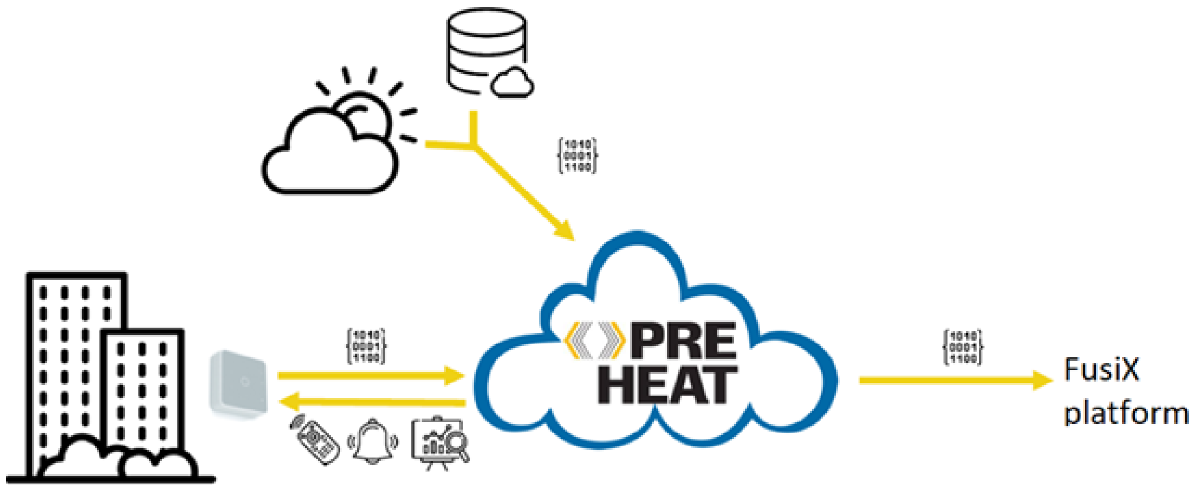


Figure 15 Data communication concept for the demonstrator.

At a later stage, a communication back from FusiX to PreHEAT or directly from FusiX to the end-users will be implemented to deliver the E-DYCE findings back to the users. However, the details of this are still to be defined in upcoming steps of the project.

As presented in section 5.5 in this report three Danish locations cover KPI families to different extend. In this section the holistic overview of DEPC framework coverage that includes EPC, DEPC asset standard (DEPC-AS), DEPC asset adapted to actual (DEPC-AA) and DEPC operational (DEPC-O) is presented and elaborated for each of Danish demonstrations.

Presented in E-DYCE D2.4 DEPC protocol provides the general possibility of E-DYCE integration, however, its real application to specific building deviates with respect to monitoring data and models availability.

Haanbaek

Overall considerations for the Haanbaek case are listed below, numbered. The numbering is used to align these statements with the content of Table 30 (see supporting statement):

1) Operational and asset rating can be performed at mono/multi zone level due to model A and model B developed for the case study (see chapter 1.4).

2) The energy demand for the DHW (operational) is measured or obtained using the methodology developed in the E-DYCE D2.3. The asset rating of this KPI can be calculated upon availability of the case-specific data, these are not available for this specific case.

3) Zone with maximum, average and minimum heating demand in operational condition refers to whole apartments since energy for heating at room level is not measured.

4) Primary energy for heating in operation assessment for a critical zone can be elaborated at apartment level.

5) Cooling is not installed therefore cooling season is the remaining time outside heating season.

6) With regards to comfort KPI family operational analysis can be performed down to room level or by space averaging to apartment level (multi). The same averaging can be performed for staircase for operational (mono) analysis.

7) Operative temperature for critical zone can be performed down to room level.

8) Additionally, analysis of operational venting routines can be carried out at a room and apartment level since all windows are equipped with window sensors. This analysis is not included as KPI outcome in DEPC protocol but can support asset adapted condition modelling and analysis of operation comfort and energy KPIs.

9) Free running operation for heating can be detected using 3-wire sensors that are mounted in supply and return of each radiator. This analysis is expected to be possible to room level.

10) Critical room for heating can be detected from modelling – as room requiring the most kWh/m2 per year or from monitoring as room that requires longest heating time (ts – tr).

11) The special focus in Haanbaek is on studying energy signature for heating, local and global (mono and multi) and effect of DHW energy use on it. Analysis will be performed both relying on measurements and simulations, but also tools and packages developed within E-DYCE

Table 30 illustrates the expected coverage of KPIs in respective KPI families and with respect assessment type (EPC/DEPC-AS, DEPC-AA, DEPC-O). The color legend for the KPI coverage in Tables 30-31 is provided in Table 29.

Table 29 The colour legend for the Table 30-31.

Indicator acc. to D2.4	Explanation
✓	Potentially available for some demo buildings, but not for the one in focus
✓	Potentially available for the specific demo building
✓	Uncertain availability for the specific demo building
✗	Unavailable for all demo buildings

Table 30 The expected coverage of KPIs within DEPC framework integration for Haanbaek demo case

For tenants								
KPI	Symbol	Assessment schema				Evaluation period		Supporting statement (see description in report)
		EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max	
Global energy performance index	Q_gl			✗	✗	month	year	
Final energy need for heating	f_Q_h			✓	✓	week	year	1)
Final energy need for cooling	f_Q_c			✓	✓	week	year	5)
Final energy need for DHW	f_Q_dh			✗	✓	week	year	2)
Final energy need for heating for an average space in the building	f_Q_h_av			✓	✓	week	year	3) 4)
Final energy need for cooling for an average space in the building	f_Q_c_av			✓	✓	week	year	5)
Operative temperature	t_op_i			✓	✓	week		6)
CO_2 concentration	CO2			✓	✓	week		6)

Fore certification party/Energy service specialist								
KPI	Symbol	Assessment schema				Evaluation period		Supporting statement (see description in report)
		EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max	
Global energy performance index	Q_gl	✓	✗	✗	✗	month	year	
Primary energy need for heating	Q_h	✓	✓	✓	✓	week/mont	year	1)
Primary energy need for cooling	Q_c	✓	✓	✓	✓	week/mont	year	5)
Primary energy need for DHW	Q_dh	✓	✗	✗	✓	week/mont	year	2)
Primary electricity need for running technical installations	Q_tech	✓	✓✗	✓✗	✗	week/mont	year	
Primary electricity need for lighting (if relevant)	Q_l	✓	✓	✓	✗	week/mont	year	
Primary energy need for heating for an average space in the building	Q_h_av	✗	✓	✓	✓	week/mont	year	3) 4)
Primary energy need for cooling for an average space in the building	Q_c_av	✗	✓	✓	✓	week/mont	year	5)
Primary energy need for heating for the critical zone	Q_h_cr	✗	✓	✓	✓	week/mont	year	3) 4) 10)
Primary energy need for cooling for the critical zone	Q_c_cr	✗	✓	✓	✓	week/mont	year	5)
Energy signature, global solar correlated	EN_SIG_2D		✓	✓	✓	month	year	11)
Energy signature, global solar correlated for the critical zone (heating)	EN_SIG_2D_h		✓	✓	✓	week/mont	year	10) 11)
Energy signature, global solar correlated for the critical zone (cooling)	EN_SIG_2D_c		✓	✓	✓	week/mont	year	5)
Fictious Energy need for free-running mode (cooling)	FICT_COOL	✗	✓	✓		week/mont	year	9)
Fictious Energy need for free-running mode (heating)	FICT_HEAT	✗	✓	✓		week/mont	year	9)
Number of free-running hours (cooling season)	n_fr_c	✗	✓	✓	✓	week/mont	year	9)
Number of free-running hours (heating season)	n_fr_h	✗	✓	✓	✓	week/mont	year	9)
Number of free-running hours for critical room (cooling season)	n_fr_cr_c	✗	✓	✓	✓	week/mont	year	9)
Number of free-running hours for critical room (heating seson)	n_fr_cr_h	✗	✓	✓	✓	week/mont	year	9)
Number of hours when CO2 level is below category I, for heating season	n_co2_h_bI	✗	✓	✓	✓	week/mont	year	6) 8)
Number of hours when CO2 level is below category I, for cooling season	n_co2_c_bI	✗	✓	✓	✓	week/mont	year	6) 8)
Number of hours when CO2 level is above category III, for heating season	n_co2_h_aIII	✗	✓	✓	✓	week/mont	year	6) 8)
Number of hours when CO2 level is below category I for the zone with maximum heating/cooling demand	n_co2_cr_bI	✗	✓	✓	✓	week/mont	year	6) 8)
Number of hours when CO2 level is above category III for the zone with minimum heating/cooling demand	n_co2_cr_aIII	✗	✓	✓	✓	week/mont	year	6) 8)
Operative temperature in the critical zone for heating season	T_op_cr_h_i	✗	✓	✓	✓	week	year	6) 7)
Operative temperature in the critical zone for cooling season	T_op_cr_c_i	✗	✓	✓	✓	week	year	6) 7)
Operative temperature in the critical zone in free-running for heating		✗	✓	✓	✓	week	year	6) 7)
Operative temperature in the critical zone in free-running for cooling		✗	✓	✓	✓	week	year	6) 7)

Magisterparken

Overall considerations for the Magisterparken case are listed below, numbered. The numbering is used to align these statements with the content of Table 31 (see support statement).

1) Asset rating can be performed at mono/multi zone level due to model A and model B developed for the case study (chapter 5.6).

2) The energy demand for the DHW (operational) is NOT measured, but can potentially be obtained using the methodology developed in the Deliverable 2.3. The asset rating of this

KPI can be calculated upon the availability of the case-specific data, these are not available for this specific case.

3) Zone with maximum, average, and minimum heating demand in simulation condition refers to whole apartments since the highest model resolution is at the apartment level.

4) Primary energy for heating in operation assessment for the critical zone is not possible (absence of the monitoring data). However, this KPI can be calculated for the asset assessment for a critical zone at the apartment level.

5) Cooling is not installed therefore cooling season is the remaining time outside the heating season.

6) With regards to comfort KPI family operational analysis can be performed, yet it must be decided how the monitored data in selected rooms within one apartment can be translated to be comparable with the asset rating at the apartment level.

7) Operative temperature for critical zone can be performed down to room level for operational conditions, but only down to apartment level for asset rating.

8) Additionally analysis of operational venting routines can be carried out at a room and apartment level since all windows are equipped with window sensors. This analysis is not included as KPI outcome in DEPC protocol but can support asset adapted condition modelling and analysis of operation comfort and energy KPIs.

9) Free running operation for heating should be possible at the building level.

10) Critical room for heating can be detected from modelling – as room requiring the most kWh/m2 per year.

Table 31 illustrates the expected coverage of KPIs in respective KPI families and with respect assessment type (EPC/DEPC-AS, DEPC-AA, DEPC-O).

Table 31 The expected coverage of KPIs within DEPC framework integration for Magisterparken demo case.

For tenants								
KPI	Symbol	Assessment schema				Evaluation period		Supporting statement
		EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max	(see description in report)
Global energy performance index	Q_gl			✗	✗	month	year	
Final energy need for heating	f_Q_h			✓	✓	week	year	1)
Final energy need for cooling	f_Q_c			✓	✓	week	year	5)
Final energy need for DHW	f_Q_dh			✗	✓	week	year	2)
Final energy need for heating for an average space in the building	f_Q_h_av			✓	✓	week	year	3), 4)
Final energy need for cooling for an average space in the building	f_Q_c_av			✓	✓	week	year	5)
Operative temperature	t_op_i			✓	✓	week		6)
CO_2 concentration	CO2			✓	✓	week		6)

For certification party/Energy service specialist								
KPI	Symbol	Assessment schema				Evaluation period		Supporting statement
		EPC	DEPC-AS	DEPC-AA	DEPC-O	Min	Max	(see description in report)
Global energy performance index	Q_gl	✓	✗	✗	✗	month	year	
Primary energy need for heating	Q_h	✓	✓	✓	✓	week/mont	year	1)
Primary energy need for cooling	Q_c	✓	✓	✓	✓	week/mont	year	5)
Primary energy need for DHW	Q_dh	✓	✗	✗	✓	week/mont	year	2)
Primary electricity need for running technical installations	Q_tech	✓	✓✗	✓✗	✗	week/mont	year	
Primary electricity need for lighting (if relevant)	Q_l	✓	✓	✓	✗	week/mont	year	
Primary energy need for heating for an average space in the building	Q_h_av	✗	✓	✓	✓	week/mont	year	3), 4)
Primary energy need for cooling for an average space in the building	Q_c_av	✗	✓	✓	✓	week/mont	year	5)
Primary energy need for heating for the critical zone	Q_h_cr	✗	✓	✓	✓	week/mont	year	3), 4), 10)
Primary energy need for cooling for the critical zone	Q_c_cr	✗	✓	✓	✓	week/mont	year	5)
Energy signature, global solar correlated	EN_SIG_2D		✓	✓	✓	month	year	
Energy signature, global solar correlated for the critical zone (heating)	EN_SIG_2D_h		✓	✓	✓	week/mont	year	10)
Energy signature, global solar correlated for the critical zone (cooling)	EN_SIG_2D_c		✓	✓	✓	week/mont	year	5)
Fictious Energy need for free-running mode (cooling)	FICT_COOL	✗	✓	✓		week/mont	year	9)
Fictious Energy need for free-running mode (heating)	FICT_HEAT	✗	✓	✓		week/mont	year	9)
Number of free-running hours (cooling season)	n_fr_c	✗	✓	✓	✓	week/mont	year	9)
Number of free-running hours (heating season)	n_fr_h	✗	✓	✓	✓	week/mont	year	9)
Number of free-running hours for critical room (cooling season)	n_fr_cr_c	✗	✓	✓	✓	week/mont	year	9)
Number of free-running hours for critical room (heating seson)	n_fr_cr_h	✗	✓	✓	✓	week/mont	year	9)
Number of hours when CO2 level is below category I, for heating season	n_co2_h_bI	✗	✓	✓	✓	week/mont	year	6), 8)
Number of hours when CO2 level is below category I, for cooling season	n_co2_c_bI	✗	✓	✓	✓	week/mont	year	6), 8)
Number of hours when CO2 level is above category III, for heating season	n_co2_h_aIII	✗	✓	✓	✓	week/mont	year	6), 8)
Number of hours when CO2 level is below category I for the zone with maximum heating/cooling demand	n_co2_cr_bI	✗	✓	✓	✓	week/mont	year	6), 8)
Number of hours when CO2 level is above category III for the zone with minimum heating/cooling demand	n_co2_cr_aIII	✗	✓	✓	✓	week/mont	year	6), 8)
Operative temperature in the critical zone for heating season	T_op_cr_h_i		✓	✓	✓	week	year	6), 7)
Operative temperature in the critical zone for cooling season	T_op_cr_c_i		✓	✓	✓	week	year	6), 7)
Operative temperature in the critical zone in free-running for heating			✓	✓	✓	week	year	6), 7)
Operative temperature in the critical zone in free-running for cooling			✓	✓	✓	week	year	6), 7)

Thulevej

Overall considerations for the Thulevej case are identical to those listed in the Table 31 for Magisterparken.

5 Demonstration case 3 – Municipality new office building, Cyprus

5.1 Description of the demonstration cases

Nicosia Town Hall is one of the first green modern passive buildings in Cyprus, Figure 16 and 17. It was designed by irwinkritioti.architecture and building physics was designed by Estia SA for the owner who is Nicosia municipality. It is a group of buildings composed of 4 buildings. Three of them are ordinary office buildings and one is an emblematic building that will operate as the council hall with the possibility of participation of 200-350 people to organise events. E-DYCE analysis will concentrate on the office buildings which are similar in design.

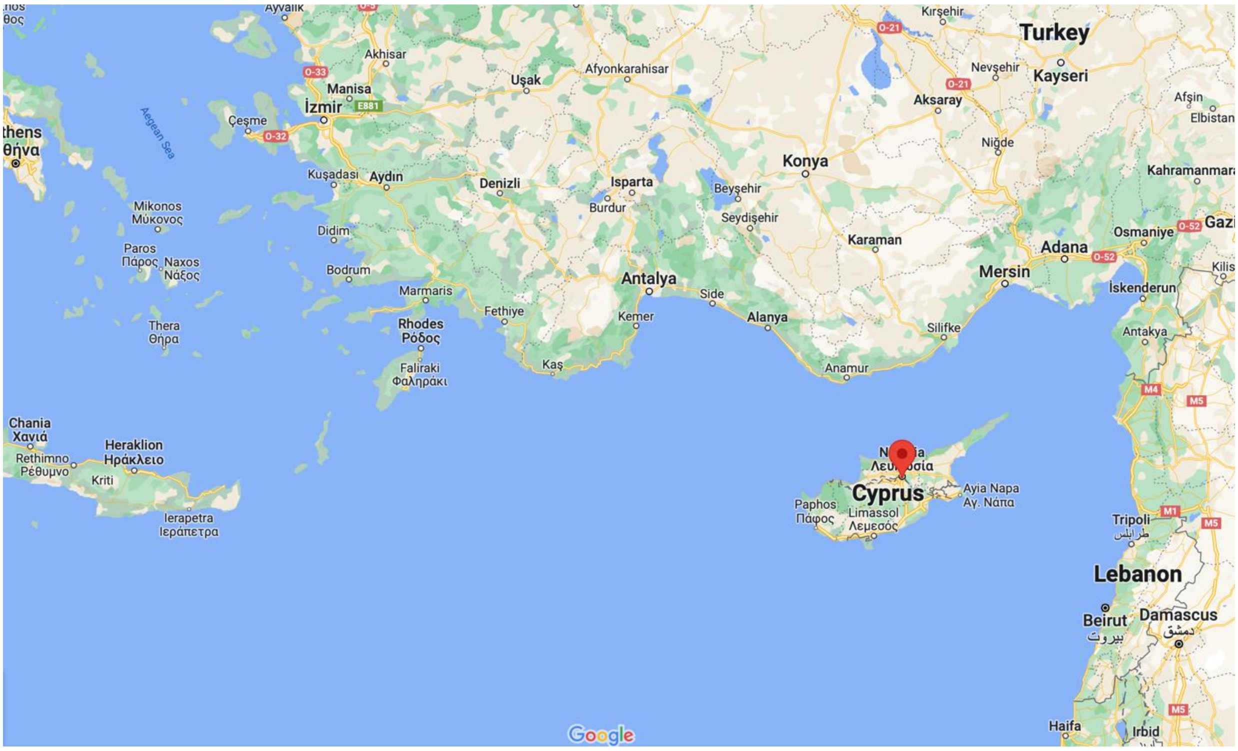


Figure 16 Cyprus (Nicosia) geographical location

New Nicosia Town Hall is not just a green building that has many green design principles to show. It is the first project in Cyprus using all the bioclimatic design principles necessary for a building to be of energy category A. The building needs for heating, cooling, ventilation, hot water, and lighting is less than 58 kWel/m2 instead of 150 – 400 kWel/m2 that conventional buildings consume. Such a building is called passive because without mechanical equipment, without moving or burning anything to support it, requires minimal energy for thermal comfort, ventilation, and lighting. New Nicosia Town Hall is a good example of the “free-running building” case study and this is the reason behind it was selected to test the E-DYCE principles.

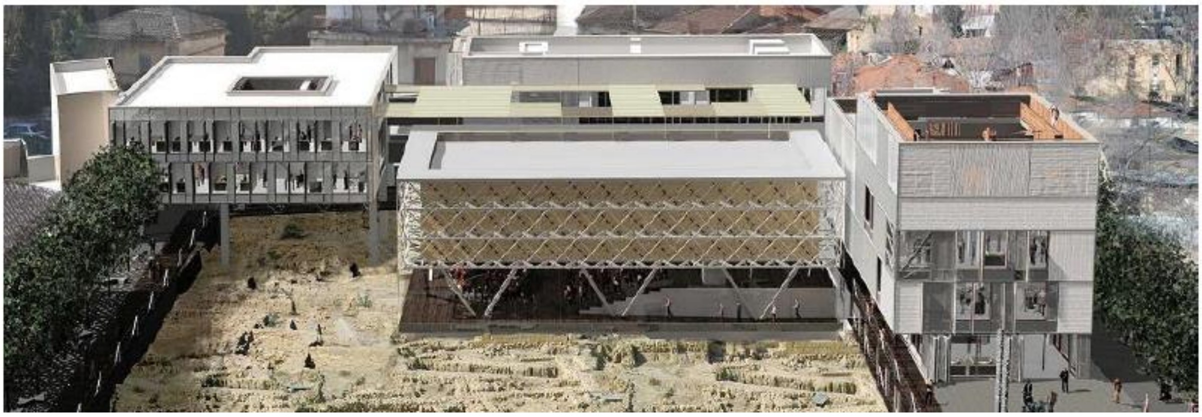


Figure 17 Buildings of the new Nicosia municipal NZEB quarter

The bioclimatic shell of the building is not only an aesthetic composition that tries to fit into the environment of the old town and the surrounding antiquities. It is equivalent to hundreds of m^2 of photovoltaics that we do not need to install. We call this building passive because no mechanism is moving to produce the energy drawn from the surrounding environment of the building. The vison was to abandon fossil fuels to make it run and instead to draw energy from the natural elements surrounding your building in the centre of Nicosia. Almost all the heat for heating in winter is provided by the sun while building shell is well insulated to prevent losses. One-third of the cooling for the summer is provided by the cool night breeze of Nicosia. The Nicosia's clear sky provides 80% of lighting. The fresh clean air is not transported by mechanical air handling units through ducts and air processing devices, but instead by the wind and thermal buoyancy forces. The building in its initial design did not have photovoltaic collectors and was still Class A. Building is equipped with small photovoltaic field covering ~20% of the roof of one of the buildings.

The building of Nicosia Town Hall is a tool for the city to better serve its citizens. It is also a working place for hundreds of people. In the initial design phase, designers circulated a questionnaire to all city employees and incorporated their preferences into the specifications of the technical solutions. More than 70% of employees prefer physical comfort rather than full air conditioning. Moreover, important are: bright offices, quietness and the ability to concentrate at work, places where they could take a coffee or lunch in a pleasant environment. A green building has the first role to serve people. The materials used are not only environmentally friendly but also human friendly. There are no adhesives, synthetic materials, carpets, synthetic paints and varnishes or other harmful chemicals in the building to emit VOCs and synthetic particles that could be breathed in by the users.

The project's construction costs were within the typical office building costs. However, the cost of maintenance and operation are significantly lower. A passive building is "technically sober". The more technically sober it is, the less maintenance it requires. For example, natural ventilation has neither operating nor maintenance costs.

List of 15 measures taken in the green design of the new town hall are listed here:

1) Thermal insulation with 10 cm stone wool on the roof and facades and reduction of thermal bridges
2) Optimum geometry, position and dimensioning of openings

3) Optimum preferably passive shading and its dynamics where necessary
4) Selection of glazing with low U-value (1.3 W/m2K) and optimum g value (0.44).
5) Night ventilation in summer
6) Natural ventilation designed to respond adequately in all seasons
7) Maximisation of thermal mass
8) Installation of ceiling fans
9) Installation of high-efficiency VRV air conditioners (COP 4.5-5.5)
10) Choice of light colours on walls and ceilings for efficient natural lighting
11) Maximization of the light transmission of glazing
12) Exclusion of staircases and common areas from the envelope
13) Use of high-efficiency luminaires
14) Use of automatic electrical switch and automatic lighting management
15) Use of environmentally friendly materials with low embodied energy

Most of these passive strategies, especially those acting on the building dynamic behaviour are not considered in the current EPC calculation framework: night ventilative cooling, presence of ceiling fans, natural lighting, partial cooling and heating excluding large parts of the building from the conditioned area, dynamic ventilation according to use and external climatic conditions.

The reason this building was selected to serve as pilot case for the E-DYCE project is to evaluate the real efficiency of these passive technologies through monitoring and dynamic simulation and to understand the free running real behaviour of the building and its impact on comfort and adapt the E-DYCE approach to real free running building.

5.1.1 Inspection protocol filled

The final architectural drawing (on the basis of which the EPC was elaborated before building construction) was verified with respect to the reality. The inspection protocol of the building was carried out to develop E-DYCE model for one of the buildings. As the buildings are designed similar and are of the same energy category A, the simulations and monitoring analysis was concentrated to building 1.3 (municipality naming) and did some punctual verifications to confirm similarity hypothesis.

The filled inspection protocol can be accessed here:

https://E-DYCE.eu/e-dyce-inspection-protocol-cyprus/

Inspection clarified mainly operational particularities, like window manual opening, shading manual use, lighting automatic use. We also verified some users remarks on comfort perception and we evaluated temperature horizontal or vertical stratification problems.

5.2 Static EPC

The buildings are of Class A according to the national EPC official method.

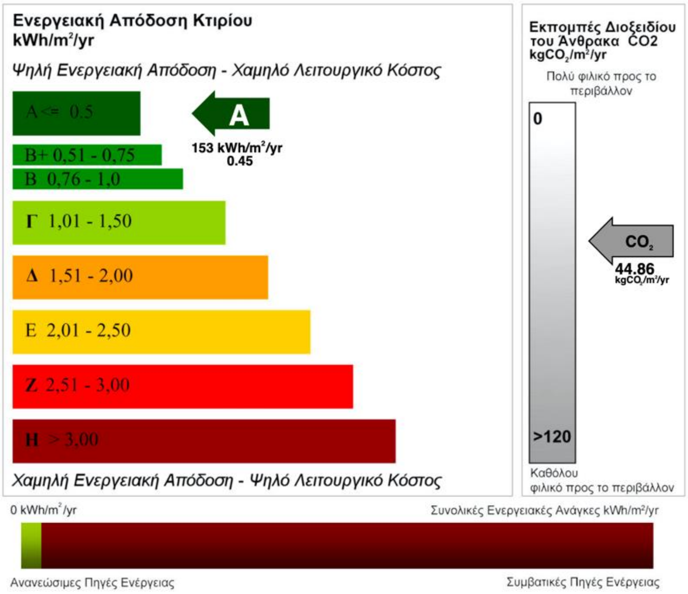


Figure 18 The official EPC shows class A*, 153 kWh/m²y of primary energy, i.e 56.7 kWh/m²y of electricity consumption from the national network for heating, cooling, ventilation, hot water, and lighting.*

Very useful information of the EPC results is the sectorial splitting of expected energy consumption (i.e heating, cooling etc.) per month.

5.3 End user (employees) feedback

Occupants of all monitored offices were visited and interviewed by Estia. The clinical method [4] was applied, that was first introduced by Jean Piaget in cognitive sciences. The method was called “clinical method” by Jean Piaget because it is like psychiatric interview, with a structured and rigorous protocol. The method consists of a structured guided interview where the subject response is influenced as less as possible by the interviewer. This method in our context leads to a deeper understanding of the user’s perceptions and motivations determining their behaviour influencing their climatic conditions. For example, users are not asked to which degree they are happy with temperature in summer, but which is the ideal temperature for them in summer and in a free discussion they are led to tell the source of the information about temperature. In that manner, for example, it is understood that in winter some people say they are happy with 25-27°C and they read this on the air-conditioning thermostat. Occupants expressed that they are satisfied with their thermal comfort, where we measure 19°C in the morning and 21-22 when they leave the office.

From the free “clinical discussions” it was firstly understood that in general the users are very satisfied with their indoor climatic conditions, their freedom to determine their comfort conditions, open or close the window, and generally the working environment. This was opposite to the initial questionary of the designers from the previous municipal buildings.

The discussion was structured in the following theme:

- How is the thermal comfort in your working environment (winter, summer, mid-season). If there were any reported problems, then users were asked to try to provide their explanation and to share, if they have a suggestion to make the comfort conditions better.

- What is your everyday practice with the windows? Here in the free discussion, it was tried to understand when and why user opens and closes the windows taking into account different seasons. Users were also asked to tell their opinion about the air quality in their office.

- What is the ideal comfort temperature in the office in summer and winter? If users had an opinion, then they were asked to tell how they know generally what the interior temperature is.

- When do you make use, why and are you satisfied with:
  - Air conditioning
  - Ceiling fan
  - Light
  - Window
  - Solar shading

- What is your opinion on the office energy premiss function and design (air conditioning, ceiling fan, window, solar shading), the use of outside stairs, energy savings.

- We end the discussion asking a general satisfaction rate between 1 (poor) and 5 (excellent).

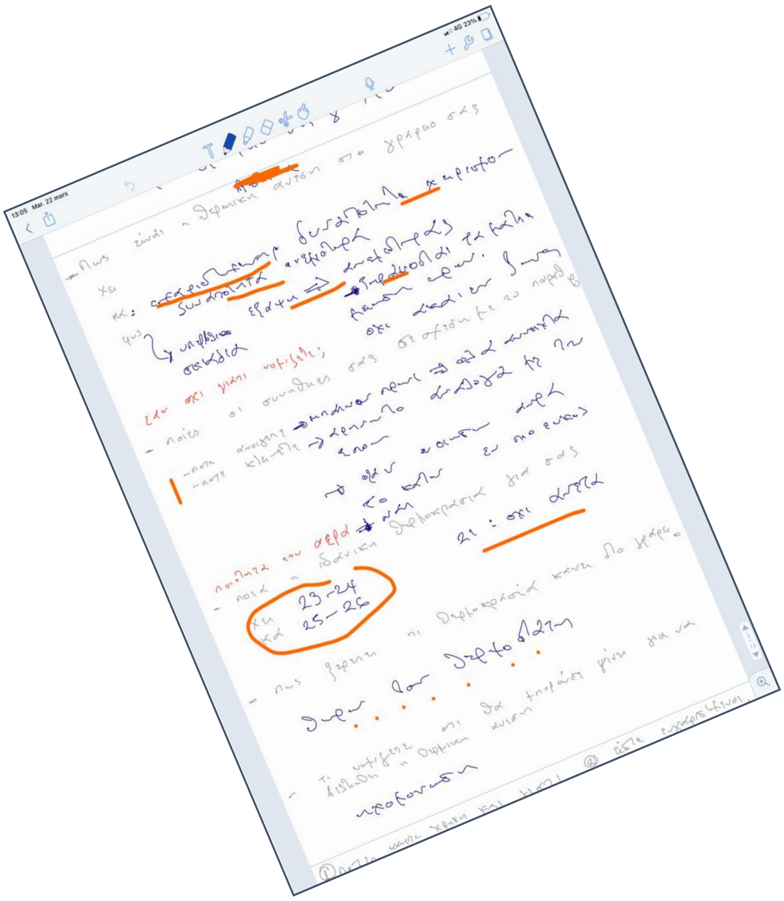


Figure 19 Example of the notes taken during a "clinical interview" of a user

The discussion took approximately 15 – 20 minutes. In cases where there were 2 people in the office, the interview was carried out simultaneously and the differences, if any, were marked. In general users were very friendly and interested in the physics of their environment and had generally strong opinions for subjects like windows, solar shading, or the use of lights. For the subjects they knew less about, like the air-conditioning functioning, they were curious.

5.4 Practical observations

The visual inspection confirmed some of the users' remarks, for example, the misuse of lighting by the building automatic control. Some other misuses were also identified, for example, the shading absence of control after working hours. All these observations should be considered as optimisation potentials.

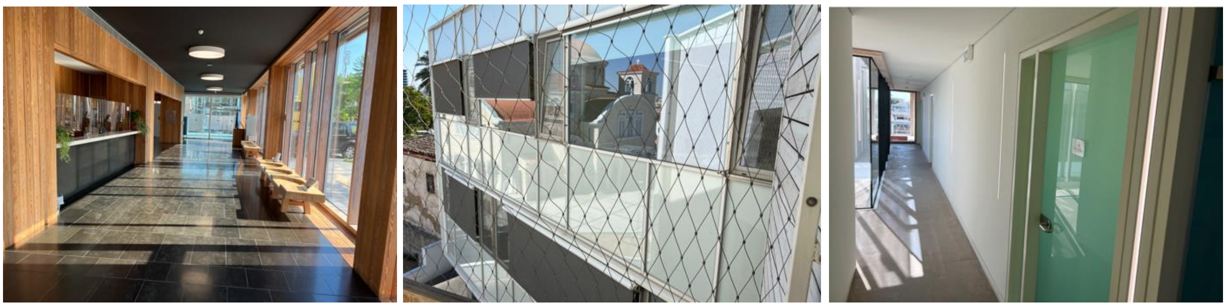


Figure 20 During visual inspection the inspector realised the lack of solar shading control and lights being turned on all the day even outside of working hours

During the inspection it was realised that there were already existing submeters for electricity for the mechanical services (VRV's and fan coil units) separated from the general electricity consumption (lighting and office equipment) for each building. There is also sub-metering for PV production additionally to the general energy consumption of all the buildings.

As there is no heat production and use of fossil fuels, the only energy consumption for all the complex including all the buildings is the electricity that is meter by the Electricity Authority of Cyprus. For the global analysis of all the buildings we may also use the electricity bills (monthly) and disaggregate the total consumption per building and use according to the submetering.

5.5 Dynamic model simulation for DEPC

DesignBuilder software was used to build the geometry of the EnergyPlus model. A multi-zonal approach was adopted for the thermal zoning to locate and further analyse the critical zones of the building. We used the same methodology and procedure as described in the sections for the Swiss case study.

As presented in Figure 21, also the surroundings of each building were included in the model to consider the shading effects of neighbour buildings.

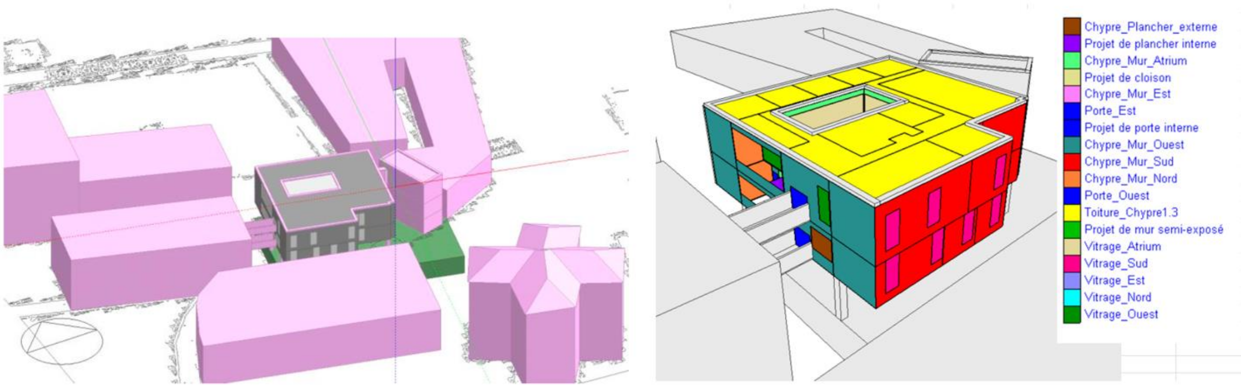


Figure 21 DesignBuilder simulation model to produce Energyplus inputs

5.6 Monitoring specification and plans

As the building behaviour is different for each orientation (this is the typical behaviour of passive buildings) we oriented the monitoring zoning according to the space specificities.

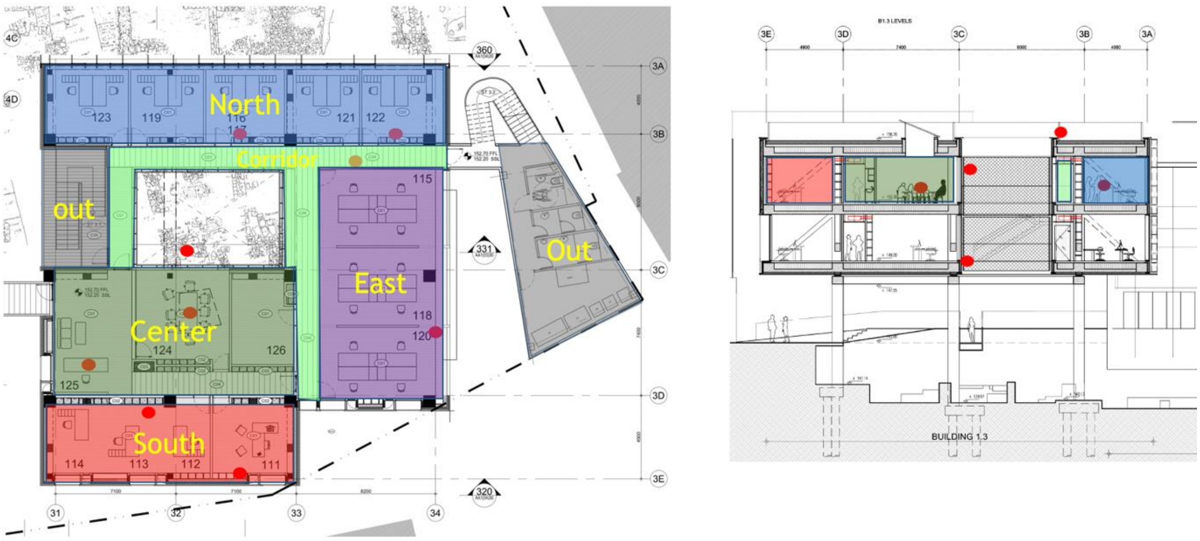


Figure 22 Figure 22 Zoning for indoor environment quality monitoring in Building 1.3.

IEQ sensors (temperature, humidity, CO2) are positioned to best available protected comfort zone, generally on or under an office desk or at the nearer open to the indoor environment shelf. For this case study we privileged low-cost commercial sensors (Netatmo) for indoor environment quality and for the local meteo (temperature and wind speed and direction). For energy consumption we used the existing network general meter and the submeters per building and use. The use of Netatmo sensors communicating with Wifi from the central sensor to the cloud and with and internal radio signal between the central and peripheral sensors was found challenging. We had to handle communication problems between the central sensor and Wifi not present in all the buildings for security reasons but also between the central and peripheral sensors. We were obliged to renounce to some measurements because of luck of Wifi connection or because of the high distance or obstacles to make communicate a peripheral sensor with the main one. However, the overall selection is satisfactory, and we manage to find good compromises for sensor position. We used some individual professional dataloggers to control the precision behaviour of the commercial sensors and to complete some measurements for very remote premisses.

For placing the sensors in the users' offices, we got a consent from the employer and from the users individually during the personal interview. No direct refusal was registered, which could be caused by the direct relation established during the interview, but also because of the user's curiosity for the results (the office users are mainly architects).

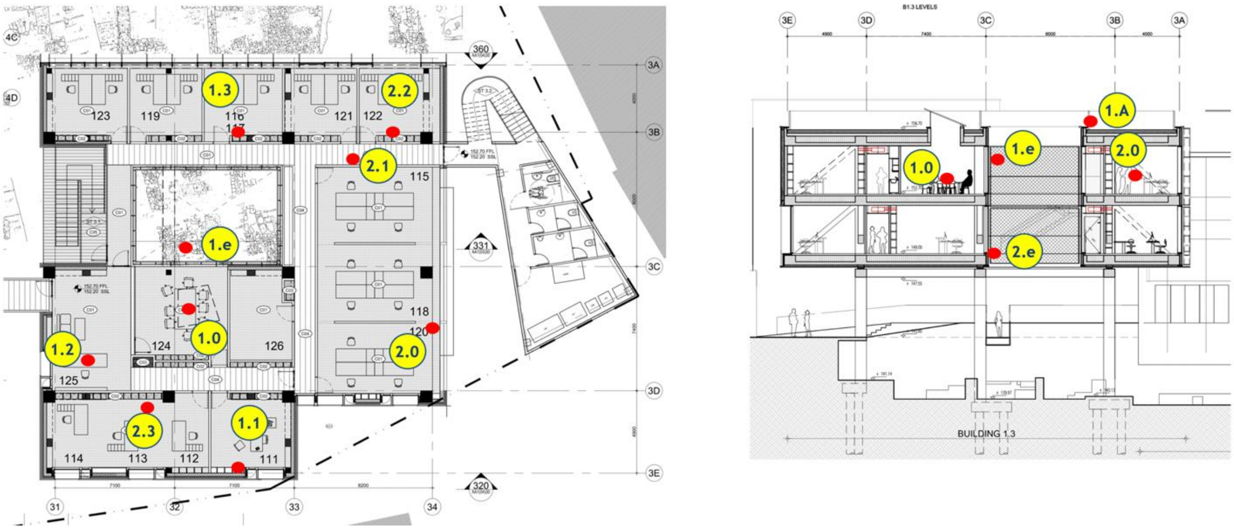


Figure 23 IEQ sensor position

5.7 DEPC framework integration

This case study enabled to test the FusiX connectivity with already existing metering devices and with commercial sensors. Pilot case building has the sensor cloud solution for analysis and data collection and FusiX environment for further analysis.

In the second year of observation, it is planned to involve the owner for energy saving measures and the users for corrected behaviour for better comfort or energy performance of the building.

The ambition is to test the real efficiency of passive measures already implemented in the building using the calibrated simulation framework and changing the design physical properties (themal mass, use of ceiling fans, use of manual shading devices). In the same way we would like to test the efficiency of some corrections, like:

- Automation of solar shading,
- Use of additional internal shading,
- More intense and systematic passive night cooling etc.

6 Demonstration case 5 – Geneva district

Geneva canton can offer several GIS services with a large range of information, not only dimensional, like the façade, roof, footprint surface areas of the building, but also energy information, like the heat consumption of buildings, generally E_{HW}, the boiler size and date of installation, the photovoltaic potential, and thermal views of the roof. In the framework of E-DYCE project two categories of information are found interesting and relevant:

- The façade, roof, and heated surface areas
- The building heat consumption since 2000 (possibility to have them for many buildings since 1994).

Figure 24 Geneva canton 3D cadastre giving surface areas of facades, roofs, or heated reference area

Moreover, we tested the possibility to use the cadastre wall and roof surface areas as inputs to the simulation models. Unfortunately, although this possibility seams interesting, it is impossible to automatically treat the data. The time for the expert to interpret and extract manually is long, but the biggest problem is that the surface logic is geometrical and not thermal. Surface is not given by orientation and the expert doesn't know if a roof surface area is heated or not. What is more, sometimes surface areas include neighbouring constructions etc.

The idea to use this information to create a first rough EPC or DEPC calculation is abandoned because the data quality is not sufficient. However, this information may be used as a complement to identify incoherence in experts surface measurements.

The only credible information that was used and found very useful is the heat reference surface area and the historical E_{HW} values including meteorological normalisation according to the reference degree days. Figure 25 shows an example with the building Centurion 3 (building 1.3 E-DYCE demo case).

Figure 25 Sample of cadastre extraction of one entrance - Centurion 3 (case study B1.3).

OCEN already uses annual heat consumption of buildings, or boiler age and size to understand the Canton's current energy use by its building stock or to tailor energy policy measures. The energy authorities use this information to set requirements on building owners whose buildings consume too much energy, for instance, buildings of E_{HW}>800 MJ/m^{2}y must undertake urgent measures and buildings of E_{HW}>600 MJ/m^{2}y must install individual energy metering per apartment or reduce their energy consumption. OCEN would like to exploit further this database and evaluate E-DYCE results and methods for upscaling.

The OCEN objectives are:

- Quantify the EPC reliability problems and make EPC labelling more reliable.
- Make predictions of energy saving measures more reliable.
- Consider low-cost soft optimisation measures, based on operating conditions modifications, in the EPC framework.
- Base energy efficiency policy in real energy consumption and not on theoretical calculations and assumptions.
- Test the real efficiency of public policy actions (evident based policy)

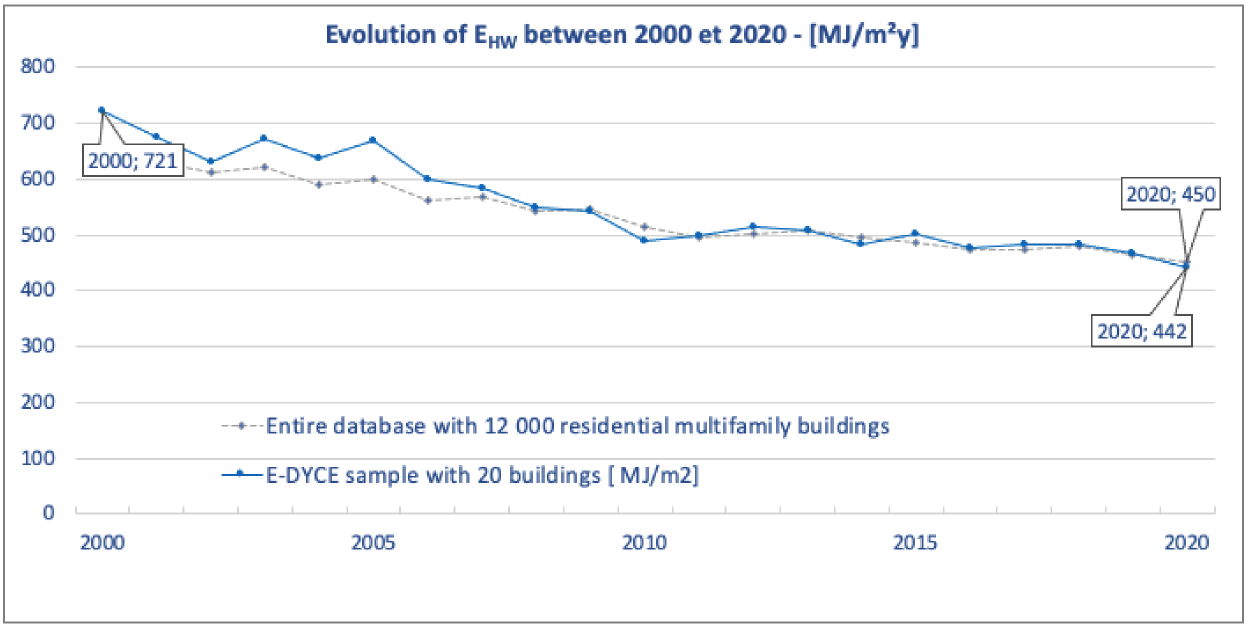


Figure 26 Evolution of the EHW of the E-DYCE sample and the entire Geneva building stock of residential buildings since 2000.

6.1 From performance gap to policy implementation gap

As soon as an energy policy measure is pronounced and seeks to change the behaviour of an actor, it must be translated into energy savings. Recent studies in the field of building energy have widely demonstrated and administered the existence of performance gaps in Switzerland [5]. When these performance gaps are identified because of decisions taken by the public authority, this results in a policy implementation gap or even a policy failure.

To give an example, let's take the well-documented case of a project seeking a very high energy performance that was the subject of a public subsidy and a tax exemption for a period of 20 years. This case does not achieve the promised performance, resulting in the non-achievement of the project's energy objectives, a misallocation of public money and a subtraction of public money from the Geneva taxpayer. This shows that the performance gap analysis goes beyond the purely energy aspects.

There is a need to quantify the performance gap to qualify the extend of the problem and even to correct inefficient past policy measures and decision. In this perspective, OCEN wishes to evaluate the current policy framework under elaboration.

6.2 Methodology

The methodology for the assessment of a sample of 20 buildings is straightforward and follow steps listed here:

- Visit of the buildings by an independent EPC expert and fill up the E-DYCE inspection protocol.
- Realise an official EPC according to current business as usual practice by the expert.
- Re-visit the buildings by E-DYCE experts (ESTIA and OCEN) for quality control of the input data.

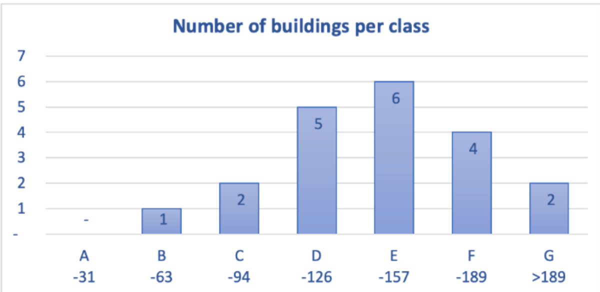
- Compare and analyse the gap between real (E_{HW}) and theoretical (EPC) heat consumption
- Use methodologies developed in E-DYCE to improve public policy monitoring.

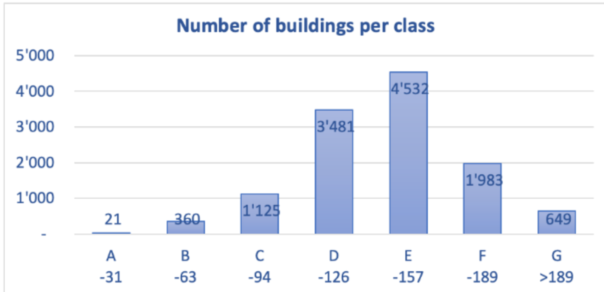
6.3 Statistical representability of the upscaling sample

6.3.1 Description of the sample

The E-DYCE statistical sample consists of 20 different entrances of multifamily residential buildings totalising 30,596 m^2 surface area owned by the same company (CPEG). The company owns 575 entrances 1,060,000 m^2 representing 5% of the Geneva Canton database. The building stock of CPEG was following the Geneva Canton energy consumption profile until 2017 but with a voluntary energy saving policy after 2017 there is an increasing gap between CPEG and Canton building stock. The total Canton multifamily residential building stock consists of 12,151 entrances of total surface area 19,339,073 m^2 in 2019.

CPEG GENEVA CANTON





Year	2019
Number of buildings	20
m^2 Heat Reference Area	30'596
Total heat consumption (GWh)	4.0
Mean E_{HW} (MJ/m^2)	466
Mean E_{HW} (kWh/m^2)	130
Tones of CO2 emissions	950
Greenhouse effect emissions kgCO2/r	31.1

Year	2019
Number of buildings	12'151
m^2 Heat Reference Area	19'339'073
Total heat consumption (GWh)	2'497.9
Mean E_{HW} (MJ/m^2)	465
Mean E_{HW} (kWh/m^2)	129
Tones of CO2 emissions	581312
Greenhouse effect emissions kgCO2/r	30.1

Figure 27 Energy profile of the E-DYCE sample (left) and the whole Canton building stock (right).

The energy database of the Canton collects data from specially authorised energy experts that translate information on the bills (kWh, m^3 of gas, l of oil, tones of wood) of final energy for heating and hot water (E_{HW}). The same experts should also declare that heated surface area measured according to the norm with a precision of ±5%.

The heat consumption data do not correspond to the total energy consumption of the EPC that include as well electricity for ventilation, cooling, lighting, and general use. To determine a partial energy class including only heat for heating and domestic hot water is used the same EPC methodology to determine $EPgl_{HW}$ for a standard building of form factor 1.3 [m^2 walls/m^2 heated floor] as defined in the technical notice SIA 2031. This gives Pgl_{HW} = 63 kWh/m^2y determining class A to 31.5 kWh/m^2y and the other classes with this module as given in Table 32.

Table 32 Scale for EHW class ranges.

Lower limit	Energy Class	Upper limit
	A	≤ 0,50 EPgl' (31 kWh/m²y)
0,50 EPgl' <	B	≤ 1,00 EPgl' (63 kWh/m²y)
1,00 EPgl' <	C	≤ 1,50 EPgl' (94 kWh/m²y)
1,50 EPgl' <	D	≤ 2,00 EPgl' (126 kWh/m²y)
2,00 EPgl' <	E	≤ 2,50 EPgl' (157 kWh/m²y)
2,50 EPgl' <	F	≤ 3,00 EPgl' (189 kWh/m²y)
> 3,00 EPgl'	G	

6.3.2 Energy consumption and CO2 emissions of the E-DYCE sample

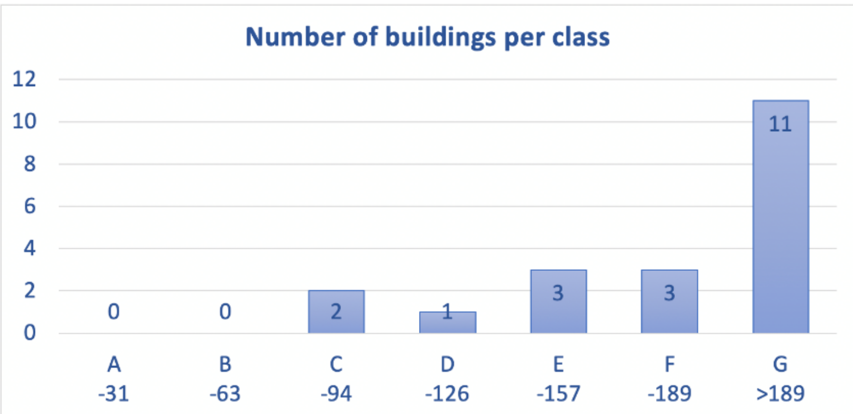
The E-DYCE sample of 20 buildings was selected to well matching in terms of energy consumption compared to the entire Canton database profile. After 2010 the sample building stock follows tightly the entire building stock energy consumption profile, Figure 26. In 2019 E-DYCE sample at 466 MJ/m^{2}y was almost the same as the whole building stock (465 MJ/m^{2}y). In terms of GHG emissions, E-DYCE sample was at 31.1 kgCO2 while the whole building stock at 30.1 kgCO2.

The sample and entire building stocks are similar also in terms of building size (1530 and 1590 m^2 respectively), in terms of typology, age distribution, and use.

6.4 Comparison between measured and EPC expected energy consumption

6.4.1 E-DYCE sample envelope class and measured E_{HW} class

As presented in Figure 28 the envelope energy performance according to the EPC is not correlated with the measured heat consumption for the E-DYCE sample of 20 buildings. Pessimistic EPC labelling could lead to false expectations for energy savings of class F and G buildings and consequently to wrong decisions.



EPC Envelope class

Measured EHW

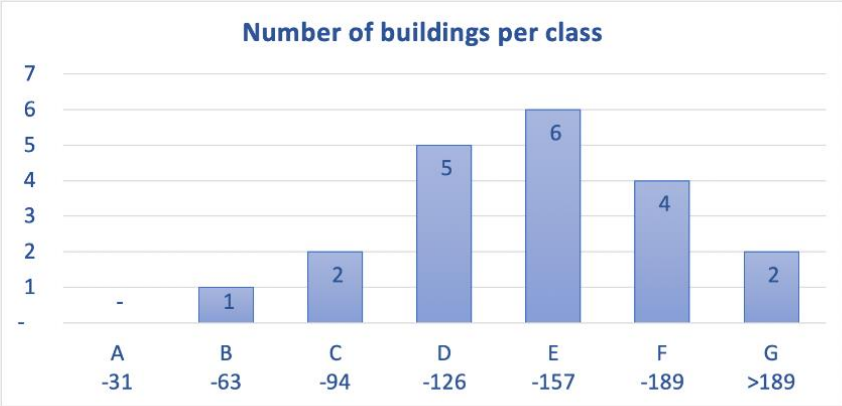


Figure 28 Envelope energy class according to Swiss EPC (top) and measured heat consumption (bottom).

Possible solutions of this problem could be:

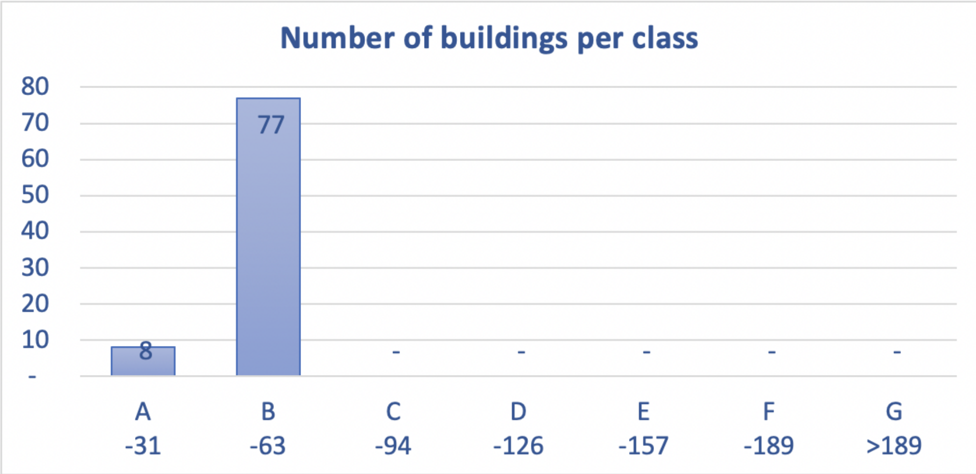
- Use the measured E_{HW} of the last 3 years as a reference for energy savings instead of the envelope energy class according to the certificate.
- Use the certificate with standard conditions only to set requirements on the envelope but not to assess energy savings.
- Adapt the conditions of use as close as possible to reality, consolidating them either by monitoring or by collecting information during the on-site inspection to calculate the expected savings.
- To avoid making assumptions about the situation before renovation, do not link the level of requirement to a relative saving (reduction of classes, percentage saving) but to a fixed objective according to the renovation context (e.g. 450 MJ/m^{2}a – 125 kWh/m^{2}y after optimisation, 200 MJ/m^{2}y - 55 kWh/m^{2}y after global renovation, 110 MJ/m^{2}a – 30 kWh/m^{2}y for a very high energy standard renovation).

6.4.2 High energy performance renovated buildings

In this section are compared 85 buildings renovated with requirements E_{HWVC}<30 kWh/m^{2}y for 8 buildings (<class A) and E_{HWVC} <55 or 60 kWh/m^{2}y for 77 buildings (<class B). The real energy performance of these labelled buildings is far (very far) from the label expectations, see Figure 29.

If the energy consumption after renovation is too optimistic according to labelling calculations, it could also create false expectations of savings and therefore generate frustrations of failure after renovation (performance gap).

Possible solution for this problem could be to use "realistic conditions of use" in the assessment of post-retrofit expected energy consumption (indoor temperature, hot water requirements, window screening, ventilation rates, heating, and cooling outputs).



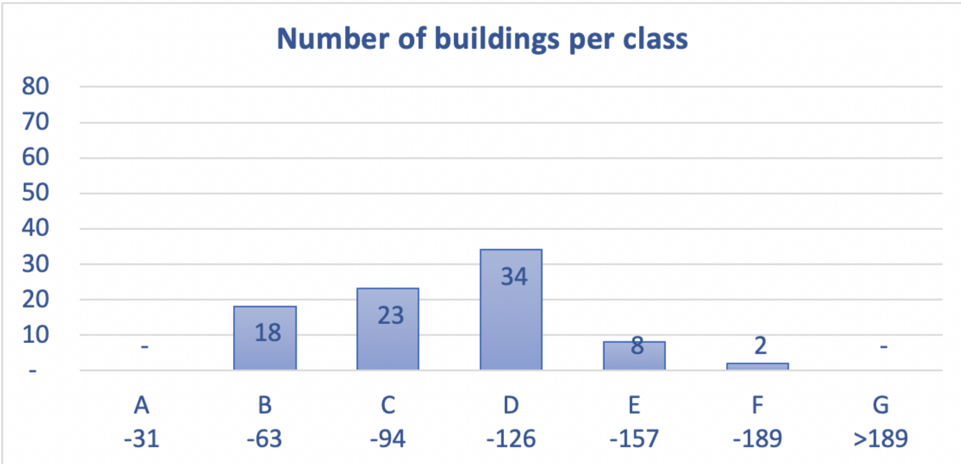


Figure 29 Expected EHW of labelled high energy performance renovations and measured EHW in 2020.

6.5 Use of measured historic energy consumption for policy implementation monitoring

This technique consists of comparing the evolution of real energy performance through years and compare a target sample with a reference sample, example given in Figure 30 for CPEG building stock. The reference sample could be a sample of buildings that did not received any renovation, but it could also be a large building stock like the entire Geneva Canton database. A real effect on energy performance of the sample group of buildings can be read by a different slope in the evolution curve.

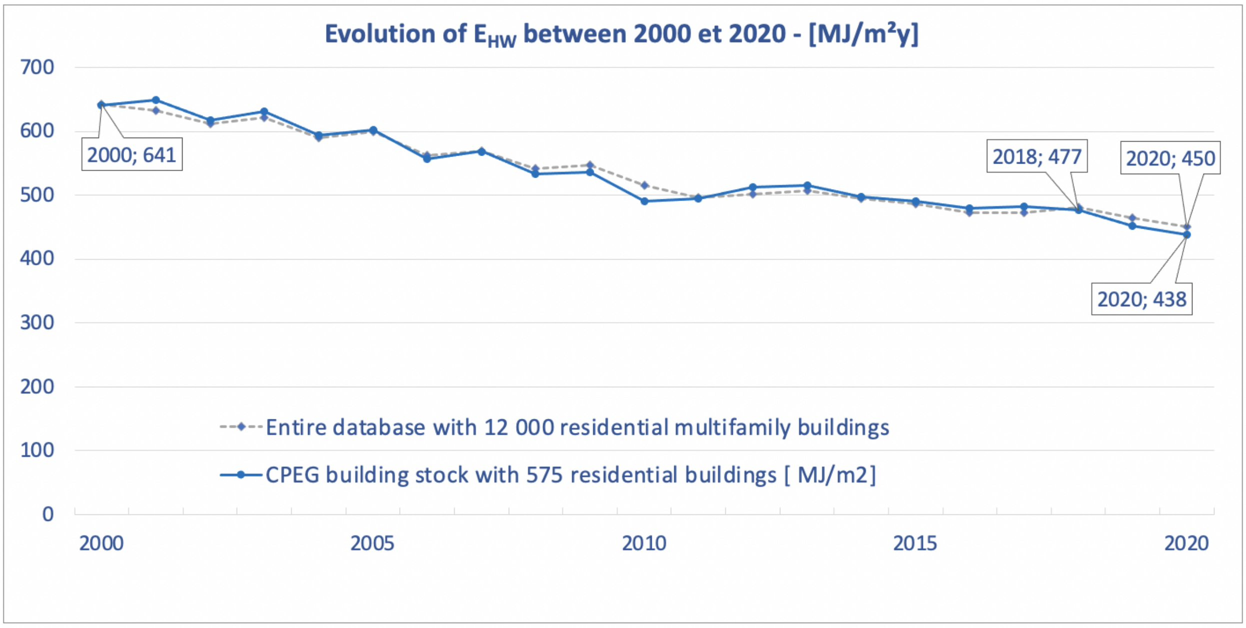


Figure 30 Evolution of the EHW of the entire CPEG building stock and entire Canton building stock of residential buildings since 2000

As can be read on Figure 30, the CPEG building stock (5% of the Canton database residential buildings) is following the general heat consumption. Same discrepancies before 2010 are due to different calculation methods translating l and m^3 of follicle fuels into MJ/m^2. We can see very clearly on this graph that the CPEG building stock is reducing its heat consumption with slightly higher rate than the entire canton building stock. In 2018 both sets of buildings were consuming 477 MJ/m^2y and in 2020 the canton set is consuming 450 while the CPEG 438. This is 12 MJ/m^2y, 2.7% lower energy consumption in 2 years. In 2021 this tendency continued but result set for 2021 is not yet complete, thus comparison stops in 2020.

This technique is powerful if you have historic energy consumption data. The result is direct for single actions applied on a number of buildings, but somebody may apply more elaborated statistical analysis to disaggregate the individual impact of multiple actions. In this study we only consider single actions [5]. In the following section this technic is illustrated on some actions showing policy failure and other showing policy succès.

6.5.1 Examples of policy success and policy failure

In the first example, Figure 31, one can see the comparison of E_{HW} of two building sets revealing policy failure. The subsidised for several years deep renovations targeting 200-210 MJ/m^2y heat consumption do not meet the objectives. The group of 85 buildings renovated in the period 2005-2017compared to the entire building stock should reduce its heat consumption to the target value. However, its mean real E_{HW} is still at 317 MJ/m^2y showing a performance gap of ~100 MJ/m^2y, more than 150%.

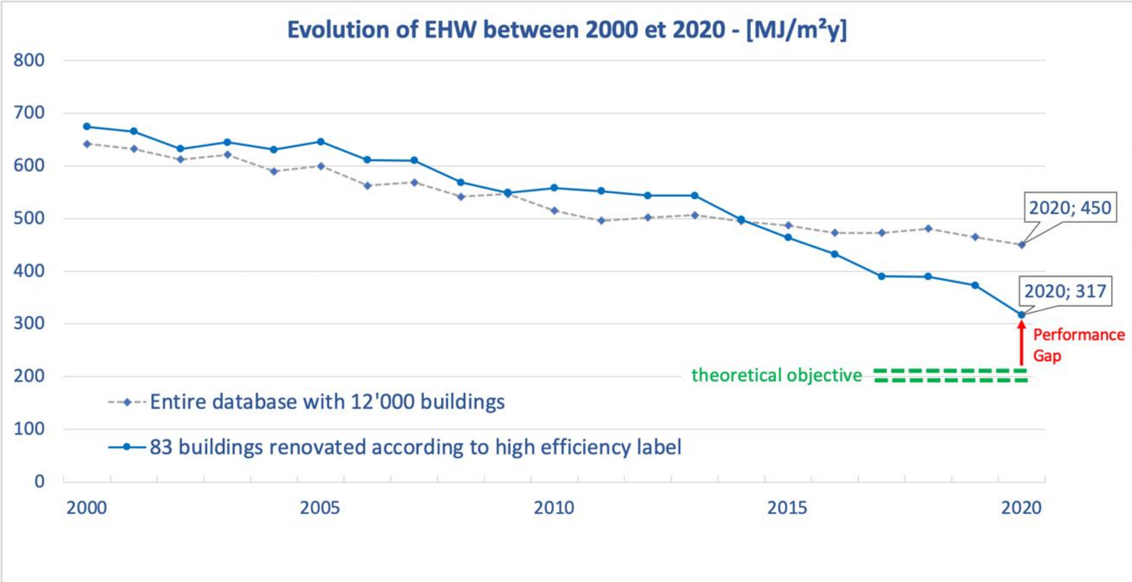


Figure 31 Example of policy failure reviled by historical real energy consumption analysis.

In the following Figure 32, two graphs are presented. Left graph presents a set of 26 buildings with single glazing non renovated windows, while right graph presents a set of 37 buildings with single glazing renovated between 2010 and 2018, replaced with double or triple glazing windows. On the comparison of these two graphs one can see a policy success of an energy law in Geneva obliging building owners to change single glazing before 2019. On the left graph can be seen that buildings with single glazing consume more compared to the Canton mean and on the right graph the effect of the law application bringing the set of renovated buildings to the Canton mean.

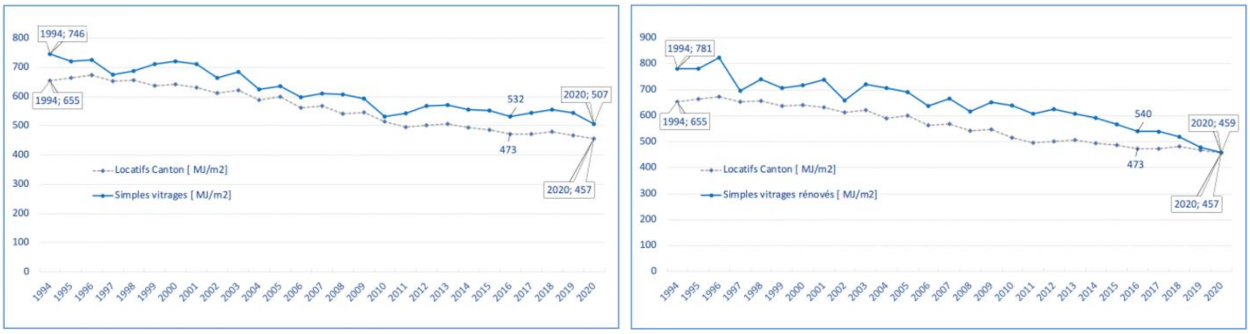


Figure 32 Left graph shows EHW of a group of 26 buildings with non renovated single glazing windows, right graph shows EHW of 37 buildings with renovated single glazing windows

6.5.2 Limits of the yearly monitoring time step

The analysis of the annual heat consumption shows the clear benefits as outlined in the previous sections. However, the method has limitations. In the example presented in Figure 33, the public authority wishes to evaluate the effectiveness of a subsidy programme for the renovation of ventilation systems with demand control ventilation and avoid dead band effects which are suboptimal from the point of view of the public good. The fact is that it takes 2 to 3 years to get feedback based on annual consumption. This waiting time makes any corrective action difficult, if not impossible. Above all, in a period of declared climate emergency and current energy shortage, this waiting time is even more problematic.

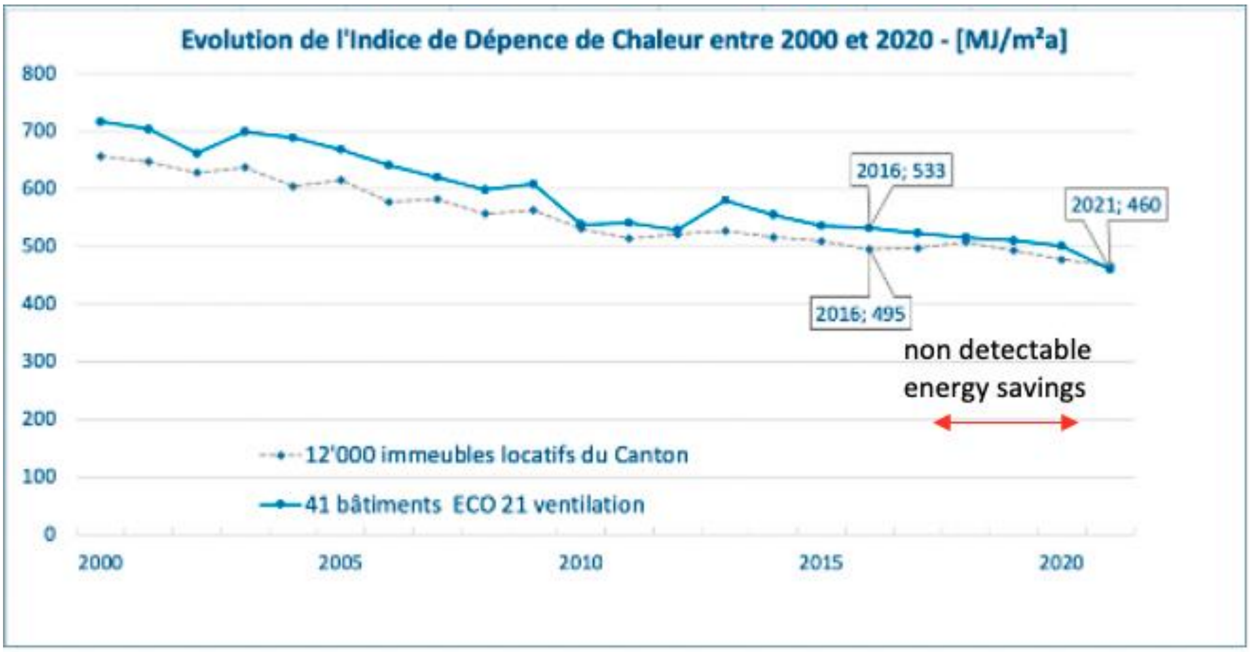


Figure 33 A set of 41 buildings with renovated ventilation system between 2017 and 2019 show a real energy reduction in 2021, 3 years after the program monitoring

6.6 Potential E-DYCE contribution to steering of energy public policies

E-DYCE proposes methods and tools in 3 dimensions: DEPC's propose a possibility of a simplified methodology to simulate dynamically the building energy performance but also to compare monitored and simulated results with shorter time step. E-DYCE also proposes a middleware infrastructure putting together the simulation and monitoring approach.

6.6.1 Dynamic simulation according to DEPC

Dynamic simulation according to DEPC enables the public authorities to promote actions acting in the dynamic behaviour of the building. For example, demand control or ventilative cooling ventilation strategies, cannot be simulated by current EPC's. The same happens in the case of smart technologies optimising the technical installation operation, such as predictive control of heating or hot water storing. We will try to test the potential this type of energy policy measures through DEPC simulations on the 4 Geneva case studies in the second part of the project, E-DYCE D5.6. In other words, it enables the public authorities to produce ex-ante policy evaluation during the designing of new measures. Case study building B1.3 participated in the public subsidise program and renovated its ventilation system to a demand control ventilation. Using the PRE-DYCE simulation framework, we would like to verify if the dynamic simulation predicts better energy savings and if ex-ante verification of the promoted measure could be reliable.

6.6.2 Monitoring with a shorter time step (monthly, weekly, hourly)

E-DYCE developed protocols for dynamic monitoring and interpretation of the results of shorter time step. Using these tools we will test on the E-DYCE case studies faster feedback after implementing policy measures. In other words, it enables the public authorities to produce ex-post policy evaluation shortly after implementation and undertake corrective measures. In sensitive energy public subsidies, public authorities may for example immediately after commissioning require declaration of monthly energy consumption to verify the subsidised measure effectiveness. In the second phase of the project, this monitoring methodology, using energy signature will be evaluated on the case study B1.3. OCEN is interested not only on the methodology reliability but also on the monitoring technical feasibility and cost.

7 Pilots integrated in the real time data in dynamic simulation architecture

In this chapter is presented overview of the pilot cases integration in the dynamic simulation architecture, namely FusiX platform, and summary of web and mobile application architecture and their functionalities to access building assessment data. As can be seen in Table 33, in each country majority of pilot buildings are connected to FusiX. In Table 33 integration of buildings is provided to Country/Building/Floor/Space. The number of sensors and an extend each pilot building is connected to FusiX is specified in E-DYCE D5.2 -5.5.

Table 33 E-DYCE pilot building's space connection in FusiX.

Country	Building	Floor	Space
Cyprus	Nicosia Municipality B1.1		
	Nicosia Municipality B1.2	2	Office 84
			Office 85
			Office 86
			Office 98
	Nicosia Municipality B1.3	2	Office 111
			Office 113
			Office 116
			Office 120
			Office 124
			Office 125
Italy	Torre Pellice school	0	Class A
			Class B
			Class C
			Class D
			Class E
		1	Class A
			Class B
			Class C
			Class D
			Class E
		2	Class A
			Class B
			Class C
			Class D
			Class E
		3	Class A
			Class B
			Class C
			Class D
	High School	0	Space 1
			Space 2
			Space 3
			Space 4
			Space 5
		1	Space 1
			Space 2
			Space 3
			Space 4
			Space 5
	Residential 01		
	Residential 02		
	Residential 03		

Country	Building	Floor	Space
Denmark	Haanbaek	0	Højrupsvej 48, st. tv.
		1	Højrupsvej 48, 1. th.
		1	Højrupsvej 48, 1. tv.
		2	Højrupsvej 48, 2. tv.
	Magisterparken	1	Magisterparken 415, 1.tv
		2	Magisterparken 415, 2.tv
	Thulevej	1	Thulevej 44, 1.th
		2	Thulevej 44, 2.tv
		4	Thulevej 42, 4.tv
Schweiz	Centurion	1	Apartment 1.1
			Apartment 1.2
		2	Apartment 2.1
			Apartment 2.2
			Apartment 2.3
		3	Apartment 3.1
			Apartment 3.2
			Apartment 3.3
		4	Apartment 4.1
			Apartment 4.2
		5	Apartment 5.1
			Apartment 5.2
			Apartment 5.3
		6	Apartment 6.1
			Apartment 6.2
		7	Apartment 7.1
			Apartment 7.2
	Loex		
	Lamartine		

With regards to accessing building information the E-DYCE user has two options available. Either to visit the web application for extended visualizations and in-depth look up or to use the Android mobile application for quick overview, see Figure 34.

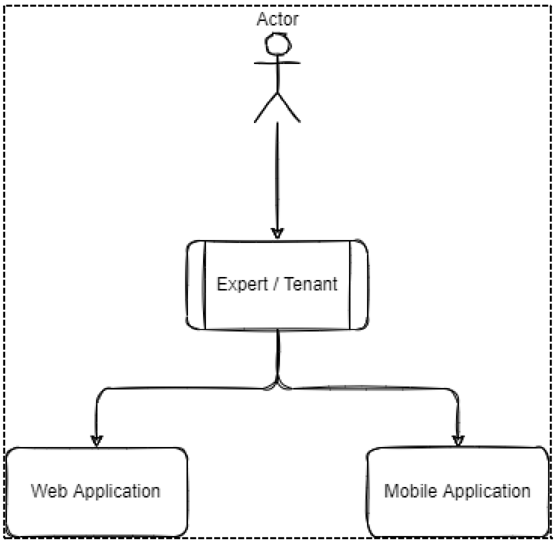


Figure 34 The E-DYCE application

In the mobile environment, that is presented in Figure 35, the user can have a quick overview of the status of a space depending on their access rights. In general, the expert users (or building owners eventually) are allowed to have an overview of each building that is assigned to them, whilst the tenants can enter only the information that is related to their apartments. For those two distinct user segments some 'swipe' views or 'button selection' views are created. Those views provide information regarding the latest known status of the space in view.

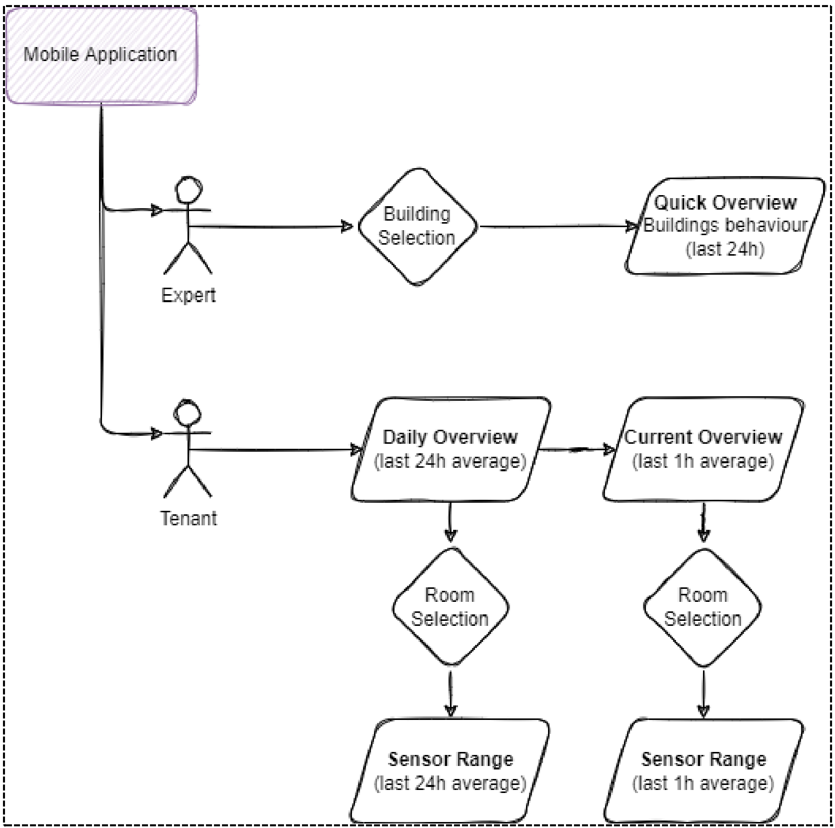


Figure 35 Mobile application architecture, access for expert and tenant

The most advanced data representation scheme can be found in the web environment, see Figure 36, from where also the application management is feasible. Both user categories (experts/tenants) have a main dashboard as landing page. An expert can have information on the building level, without entering specific details of the apartments that compose a building. On the other hand, a tenant, may not be able to see the whole building's behavior, but they have an analytical apartment dashboard at their disposal. All the sensors can be visualized there per room. Some basic KPIs are also available to guide the user regarding the indoor environment quality of their space.

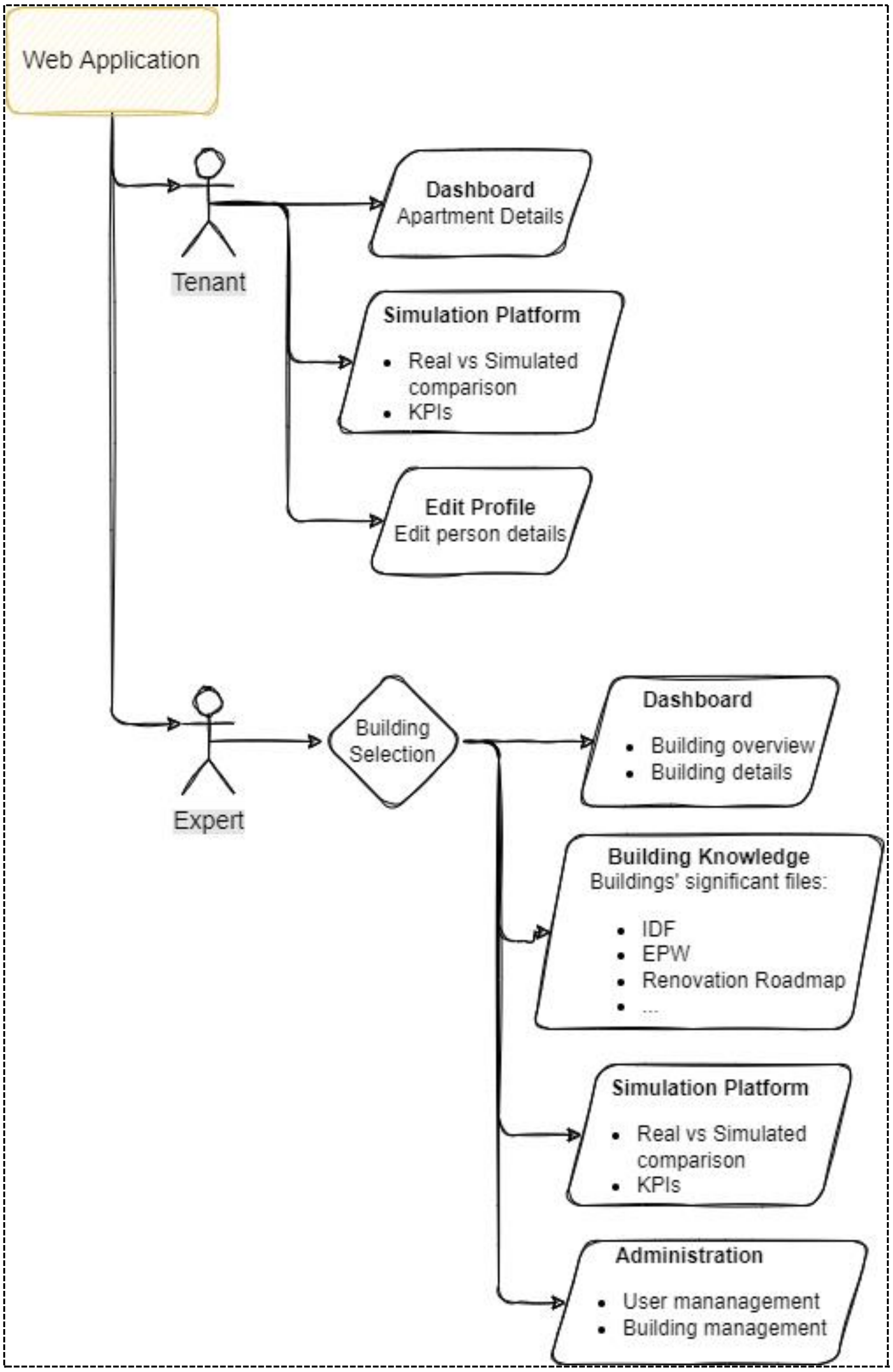


Figure 36 Web application architecture, access for expert and tenant.

A tab, connected to the outcome of the simulation platform is available to both user categories, providing results of the simulations. The results are presented in a comparative way, where the simulated (ideal) behaviour is compared against the real (from the monitoring).

An expert may also use the 'Building Knowledge' tab, where all the important documents of a building are kept. Vital files, like an IDF, an EPW and the Renovation Roadmap have a significant place in this page and are directly linked to the simulations. Any other file of an expert's interest can be uploaded/downloaded to or from this page. The idea behind it is a digital building's portfolio for simulation files, drawings, bills, etc.

Finally, some administrative tabs are available to both user categories. Either for editing one's profile (for tenants) or registering and configuring new buildings and giving access to particular data.

8 Bibliography

[1] L. Ghirri, Niente di antico sotto il sole. Scritti e interviste, Quodlibet, 2021.

[2] J. Snell, D. Tidwell, P. Kulchenko, Programming Web services with SOAP, 1st ed, O'Reilly & Associates, Sebastopol, CA, 2002.

[3] D. Claridge, M. Paulus, Building simulation of practical operational optimisation, in: J. Hensen, R. Lamberts (Eds.), Building Performance Simulation for Design and Operation, 2nd ed., Routledge, London ; New York, 2019: pp. 399–453.

[4] Vinh Bang, Textes choisis, LA METHODE CLINIQUE ET LA RECHERCHE EN PSYCHOLOGIE DE L'ENFANT,FondationJeanPiaget,1988/2022. https://www.fondationjeanpiaget.ch/fjp/site/textes/VE/Bang66methodeclinique.pdf

[5] Lang, Lanz B., Climate policy without a price signal: Evidence on the implicit carbon price of energy efficiency in buildings, Journal of Environmental Economics and Management, 2021

[6] Cozza, S., Chambers, J., & Patel, M. K., Measuring the thermal energy performance gap of labelled residential buildings in Switzerland, Energy Policy, 137, 111085, 2020.