Establishing an Integrated Monitoring Concept for the Vienna Lighthouse Project Smarter Together

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1 ABSTRACT

Within the EU Lighthouse Project "Smarter Together", the City of Vienna has been working during the last three years together with the Cities of Munich and Lyon following a P2P learning process to implement a set of integrated smart solutions with focus on holistic buildings refurbishment for low energy districts, onsite renewable energy supply (RES), e-mobility solutions and ICTs. This endeavour aims to support the city vision in transforming Vienna towards sustainable, resilient and liveable city along the ongoing urban transformation and energy transition.

For several demo site projects an integrated monitoring concept has been established and tested within a co-creation process encompassing city key stakeholders and various actors from research institutions, industry and building contractors. The developed concept comprises the whole automated process of sensor-based data collection, transfer to and storage on the city's Data Management Platform (DMP) and the subsequent processing, visualization and generation of related key performance indicators (KPIs). The KPI-based monitoring process seeks to track and monitor the impacts of the implemented solutions for the city demo sites beside their potential contribution to achieving city's sustainable development targets following an intracity rollout phase and a future replication plan in selected follower cities.

The established process highlights the importance of intensive communication among all stakeholders. The generated KPIs for the refurbished buildings demonstrates the importance of establishing a co-creation process gathering buildings owners, construction companies, city's governance, research institutions and IT utilities responsible for developing and maintaining Vienna's DMP and the following provision of smart services to third parties.

The KPI-based monitoring shows that for the use cases of building refurbishment (comprising 65060 m^2 of social housing and 3800 m^2 public building) the achieved energy saving by building efficiency measures will reach annually about 4760 MWh. The fossil fuel saving through substitution effect by onsite renewable energy generations (PV, solar thermal, geothermal heat pumps) will reach about 451 MWh. The resulting CO2 reduction by building energy saving and RES will reach about 1423 tCO2 annually. The results underline the importance of the implemented smart solutions in achieving Vienna Energy Framework Strategy pursuing a clear decarbonization path and thus supporting its transformation vision towards inclusive, sustainable and liveable city.

The deployment of the successfully implemented and monitored solutions is ongoing. Based on the lessons-learned and the gained best-practices, it is expected that the implementation of an appropriate replication plan will enable by the year 2030 that significant part of the existing old social buildings in Vienna will be refurbished and monitored following the integrated monitoring concept established within Smarter Together project.

2 INTRODUCTION

The ongoing urban transformation will be predominantly controlled by the conceived transformation towards sustainable, efficient and low carbon energy system at the various levels of building, district and urban scales. The successive demonstration of integrated smart energy solutions at those levels will pave the way towards inclusive, sustainable, resilient and liveable cities and urban areas, at their centre stands the aspired concept of Smart City (SC, (2015). A complex, multi-disciplinary system that makes use of the highly condensed socio-economic activities and seeks -among others- to optimize the synergies resulting from the intersections between the different sub-systems -e.g. energy, water, land-use, transportation, ICT,

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infrastructure and logistics, etc.- in order to attain the conceived sustainable and resilient urban system (Energy Ahead, 2016) with optimized resources use as well as commodities and services flow.

In supporting this development path, the EU project Smarter Together brings together the three Lighthouse cities (LHCs) Lyon, Munich and Vienna to demonstrate the implementation of integrated smart solutions (in buildings, energy and mobility) within a holistic approach and following an integrated co-creation process covering cities key stakeholders. The groups of the smart solutions being currently in the final implementation stage within the LHCs cover 1) citizen engagement and stakeholder involvement in the established co-creation process, 2) holistic refurbishment of private and public buildings to achieve low energy districts by significant enhancement of building shales insulation beside integrating district heating and local renewables, 3) Connecting renewable energy sources 4) integrated e-mobility solutions of different e-vehicle including charging stations, and 5) data management platforms (DMP) & smart services to manage the storage, processing and visualization of the data collected from the implemented solutions for each LHC (smarter Together, 2018). Smarter Together runs from 2016 to 2021 including a subsequent phase of monitoring and evaluation.

Within the project the LHC Vienna has been working on demonstrating several integrated smart solutions focusing on buildings refurbishment, e-mobility and ICTs. Buildings refurbishment cover renovation activities to highly efficient building envelope (insulation of building shale, windows and roof), modernization of the building energy supply system (for space and water heating and lighting), increasing the contribution of onsite RES. The solutions are being implemented in a demonstration area located in the 11th south-eastern city Vienna district Simmering. Simmering is a classic workers and industrial district with about 21000 inhabitants of diverse cultural backgrounds and the majority of them belongs rather to the lower income group of Vienna city. The refurbished buildings are owned by the Vienna city covering the three residential social housings of Hauffgasse 37-47, Lorystraße 54-60 and Herbortgasse 43 with a total floor area of 65000 m2 and 1300 inhabitants in addition to a public building of the Secondary schools Enkplatz 4 with a refurbished area of 3800 m2 (smarter Together, 2018), (D2.3.3, 2018).
The implemented e-mobility solutions contribute also to the city sustainable development with main focus on environmental impacts -to reduce CO_2 emission and local pollution-, testing the energy saving of e-solutions compared to the reference fossil running vehicles beside changing mobility behaviour by testing alternative models like e-car sharing. The demonstrated solutions within Vienna LHC cover the transport modes of E-Vans, E-Forklifts, E-cars beside E-car and E-bike sharing.

The ICTs play and essential role in realizing the monitoring concept from the level of sensor-based data gathering to the KPIs calculation. Key element herewith is the established DMP within each of the LHC. The realized DMPs support the establishment of comprehensive big data sets of various domains affected by the Smarter Together project covering building management systems, production of onsite RES, management of mobility systems (including e-car/bike sharing). Moreover, the realized DMP helps facilitating an automatized data transfer between project partners that stimulates a proper understanding on how the various infrastructure components are working and which additional applications for the city end users can be created. Furthermore, the DMP plays a central role in establishing an integrated monitoring process based on extracting KPIs related to the particular measures realized within the project demonstration areas (e.g. buildings energy saving and CO_2 reductions). This helps in evaluating the impact of the implemented solutions and their future potential in supporting the desired urban sustainable development of the considered city.

In addition to the mentioned direct effects, the realized solutions and monitoring infrastructure implies indirect socio-economic benefits for citizens, cities public authorities and key actors in term of commercial exploitation and new business models stimulated by increased contributions to open data government. This can be demonstrated by lower energy bills in the demonstration districts, citizen-driven data strategies and improved co-creation capacity on local level. This again can boost the replication potential of the realized integrated smart solutions.
Essential part for the successful rollout and replication of the integrated smart solutions is the development of an appropriate KPIs-based monitoring process that enables tracking and monitoring the impacts of the implemented solutions within the city demo sites. The monitoring process creates quantitative and qualitative

data, where the KPIs are calculated using the ongoing measurements of the post implementation phase compared with the historical data as refence benchmarking. The documentation of the process is a crucial step and leads to a detailed insight into the benefits of the measures.
The careful selection and evaluation of representative KPIs help to enhance the implementation process, maximize the positive impacts of the assigned solutions and figure out their future rollout and potential contribution to the concepts of smart city along the sustainable development plan of Vienna city. Finally, a well-established KPIs-based monitoring process sets the course for a successful future replication plan in other cities.

3 P2P LEARNING PROCESS

Smarter Together focuses on an intensive multi-level knowledge management supported by a peer-to-peer (P2P) learning process established among the three LHCs. The peer-to-peer (P2P) learning process established among the three LHCs builds with its lessons-learned and best-practices the fundament for widescale rollout of the solutions within the LHCs and the further replication within a set of Follower Cities (FCs) comprising Santiago de Compostela, Sofia and Venice. Moreover, the two additional observer cities, Kyiv and Yokohama, will adopt and replicate the successfully implemented solutions benefiting from the experience of the LHCs and their FCs.
A key element in this P2P learning process is the establishment of participatory co-creation processes spanning the cities key actors and stakeholders including building owners, tenants, citizens, city governance, real states companies, energy supply utilities beside industry and research organizations. Integrating all those city stakeholders within the planning and implementation process is vital for the successful implementation of the smart solutions and represents an important guarantee to ensure their alignment with the city's future transformation vision and sustainable development plan. Moreover, the applied P2P process promotes an intensive governance learning process by applying different governance approaches reflecting structural, cultural and historical background of each city.

Following the conceived P2P learning process in implementing integrated smart solutions at building and district levels of the LHCs Lyon, Munich and Vienna, an integrated monitoring process has been developed. The monitoring process relies upon carefully selected KPIs aiming at evaluating and tracking the sustainability impacts of the implemented solutions in social, economic and environmental dimensions. This covers the impacts of energy saving by improving the building shale efficiency, contribution of RES, reduction of CO_2 emission and air pollutions, citizen and governance participation, reduction of energy bills and maintenance cost per dwelling and enhancing the living comfort.

4 THE INTEGRATED CONCEPTS OF BUILDINGS MONITORING

For the implemented smart solutions in buildings and mobility an integrated monitoring concept has been established following a co-creation process encompassing various city stakeholders. It covers the whole automated process of sensor-based data collection, transfer and storage on the Vienna data management platform and the final consolidation and processing to timely visualise the results and generate related KPIs covering inter alia achieved energy saving, RE contribution and CO_2 reduction. Figure 1 shows schematically the flow chart of the automated data monitoring process. Detailed description to the involved stakeholder and the technical specifications of the monitoring process by of the Vienna use cases is available in the Maintenance Plan of Smarter Together project (MP, 2018)[1].
Figure 1 presents the various steps of the monitoring concept. Using an M-Bus interface, each of the onsite meters for electricity, heat, gas and water is equipped with an M-Bus module and linked further to an M-Bus Master. The Sampling frequency of raw data measurement depends on the physical behaviour and the underlying process of the measured parameters and amounts to 15 minutes. The measured data are then transferred to the Energy Management System (EMS) at MA34 (Municipal department, Building and facility management) using the Supervisory Control and Data Acquisition (SCADA) system. The data are then stored at the Smarter Together Data Platform at M01 (Municipal department, Wien Digital) where they are then processed and visualized. Finally, for processing and calculation of KPIs the data are then provided to the AIT.

[1] MP, 2018. Maintenance Plan, Deliverable D6.2.1, Smarter Together

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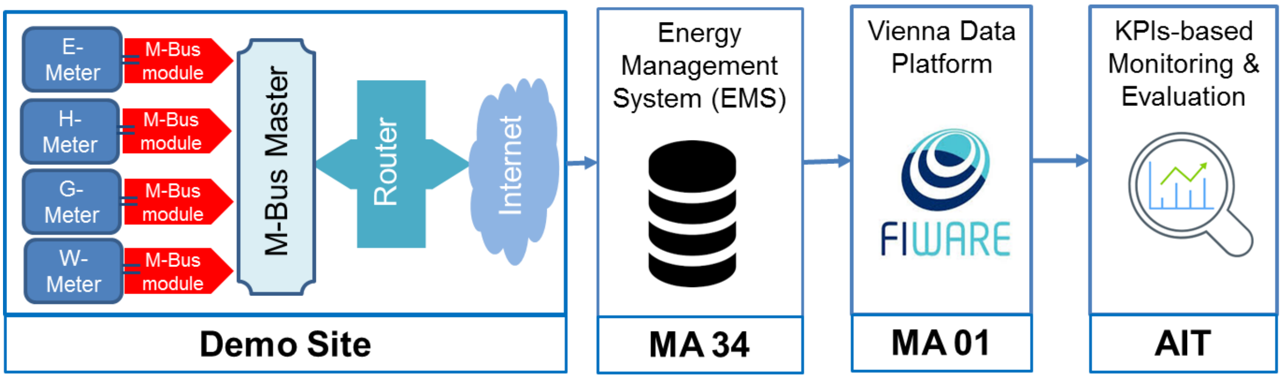

Figure 1: Schematic flow diagram of the integrated monitoring process for the Vienna lighthouse demo sites.

4.1 Meter Concept at the Demo Sites

For each demo sites of the refurbished projects a meter concept has been developed showing the M-Bus-capable meters for the consumption of space heat, hot water, electricity of public area and lifts and cold water. The refurbished buildings are owned by the Vienna city covering the three residential social housings of Hauffgasse 37-47, Lorystraße 54-60 and Herbortgasse 43 with a total floor area of 65000 m2 and 1300 inhabitants in addition to a public building of the secondary schools Enkplatz 4 with a refurbished area of 3800 m2 (Smarter Together, 2018).

The Hauffgasse represents the biggest refurbished building in Vienna LHC. The building complex is a social housing owned by the housing association BWSG. It consists of 3 separate blocks comprising 486 flats with 1051 tenants (Figure 2). All flats are supplied with space heating and water heating by the municipality district heating operated by the utility KELAG.

Figure 2: The final stage of building refurbishment at Hauffgasse

To demonstrate the working principle of the monitoring step at the demo site Figure 3 demonstrates schematically the Meter Concept of the Hauffgasse. The other buildings follow similar approach with different technical specification. Space and water heating demands are monitored with two separate meters. Besides, two rooftop PV systems with total nominal capacity of 76 kW is installed on the top-roof of Block 1 and Block 3 occupying about 370 m^2. The generated electricity is completely used for water heating for which a separate e-patron is considered to convert PV-electricity directly into heat. After the building refurbishment, new apartments were added to the three blocks for which two additional heat meters -for space heating and water heating- have been added to the two already existing meters resulting in 4 heat meters pro block. A total of 12 heat meters are considered for monitoring the heat consumption. 24 electricity meters are installed to monitor the general electricity consumption of the common area, lifts, Sauna, community centre, heat patron, charging station of e-car sharing and electricity generation of the two PV panels. For each of the 3 blocks one additional M-Bus capable water meter is installed to monitor municipal water consumption. Altogether, the building facility will be equipped with 39 M-Bus capable meters.

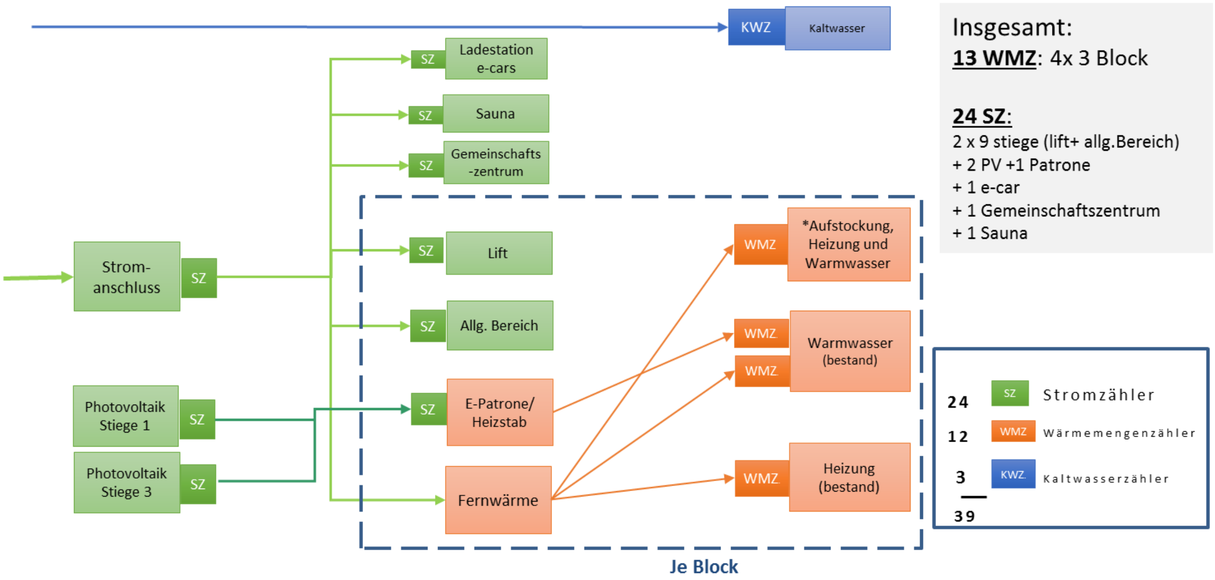

Figure 3: Meter concept for the demo site of Hauffgasse (after refurbishment)

Table 1 shows a list of the M-Bus capable meters for the 4 buildings. Altogether 19 heat meters will be implemented for monitoring the lumped consumption of building space and water heating, 43 for electricity consumption, 4 for electricity production by local PV, 3 for the lumped building gas consumption and 7 for lumped water consumptions. Altogether 76 meters are used to monitor the four Vienna demo sites buildings.

Table 1: summary of the M-Bus capable meters for monitor energy consumption in the 4 Vienna buildings demo sites.

Metre Type / Building	Heat meters	Electricity meters	PV-Production meters	Gas meters	Water meters	Sub Total
Hauffgasse 37-47	12	22	2	-	3	39
Lorystraße 54-60	1	8	1	2	1	13
Herbortgasse 43	1	9	-	1	1	12
School Enkplatz 7	5	4	1	-	2	12
Grand Total	**19**	**43**	**4**	**3**	**7**	**76**

4.2 Historical Data of Buildings Energy Consumption

The historical data of building energy performance before the refurbishment (initial start was the first half of 2018) have been collected and evaluated. The data refer to several past years ahead of the refurbishment and vary between three and seven years for the social housings and six months for the school building. The available data cover space and water heating consumption, gas consumption and general electricity consumption related to the building common activities and adds up from different sources (e.g. general lighting, elevators, intercoms, heating pumps, receiver amplifiers, cable TV) (Clausnitzer et al, 2009), (Bogenstätter, 2007). All the processed data correspond to the collective consumption at block or total building level. No dwellings specific data have been processed due to private data protection rules.

The collected data are on monthly basis for the of the three-social housings whereas for the school building data with a sampling rate of 15 minutes are available.

Processing and evaluation of buildings energy consumptions data and their related energy supply options (of heat, gas and electricity) before building refurbishment builds the baseline data against which the impacts of the implemented smart solutions are measured. This approach builds the basis of the KPIs-based monitoring process that aims to calculate the achieved energy saving, fuel substitution, RES contribution and related CO_2 reduction resultant of the completed refurbishment.

Furthermore, the energy performance certificates (EPC) before and after the refurbishment have been consulted for the purpose of comparison with the real measured building specific data for both plausibility check and evaluating the meaningfulness of EPC for the monitoring process. This is important due to the fact

that the building heat consumptions given in the EPCs are mostly estimated based on theoretical correlations, constitutive assumptions and whether adjusted data for the Heating Degree Days (HDD) and outdoor temperatures (HGT, 2013). Thus, they represent a good estimation of the real building heat consumptions.
Moreover, the comparison of the EPCs before and after refurbishment offers the possibility to calculate the theoretical target KPIs at the early stage where no data are available for the refurbished building.
Figure 4 depicts in an exemplary manner the collective result of the monthly heating and hot water demand for block 1 of the Hauffgasse for the years 2016. In addition, the average monthly temperature is also included based on actual measurement of the outdoor temperature near the building site. The monthly distribution of heat demand demonstrates the clear dependency of heating demand on the outdoor temperature and the resulting seasonal variation. One exception is the observed high heat consumption for the month March. The daily evaluation of the outdoor temperature revealed significant temperature drops in several days of the month, a clear reason for the unexpected jump in heat demand. This type of plausibility and consistency check has been applied for all data giving more insight into the dependency of the building heat and electricity consumption on various physical parameters. This approach is helpful for the later assessment of the generated KPIs within the monitoring process.

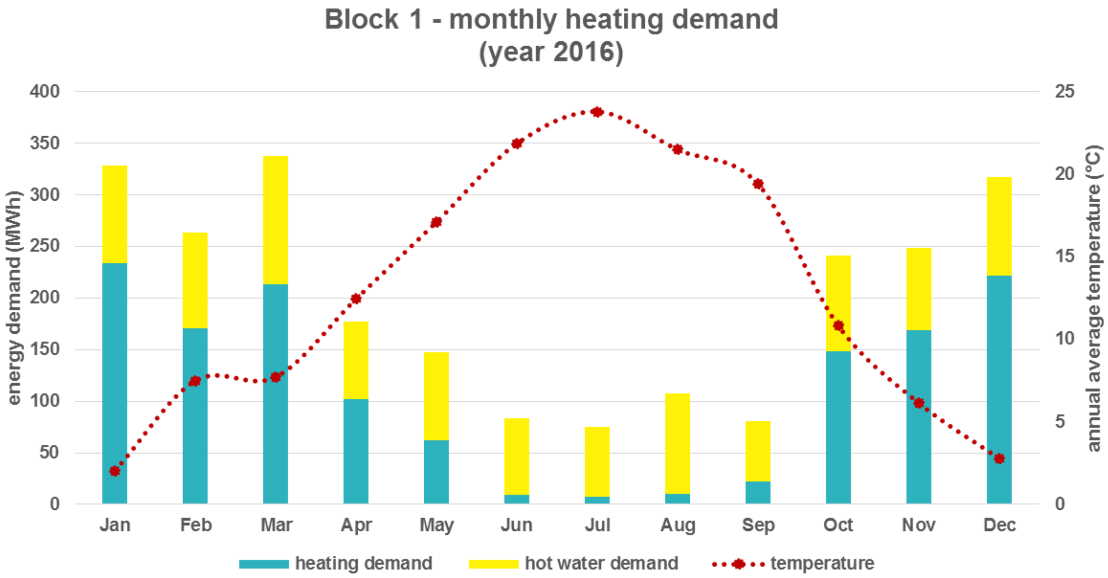

Figure 4: Example of the monthly heating demand of Block 1 from 2016 with the monthly average temperature (in MWh), (BWSG, 2017).

4.3 Selected Target KPIs of Refurbished Buildings

As to this stage, real measurements of various data on building energy consumption, local RES generation are still not available, indicative calculation have been performed based on the data given in the EPCs of the four buildings before and after the refurbishment. This provides a good estimation of the expected impacts of the implemented smart solutions related to energy efficiency and RES measures. In the second half of 2019, when building refurbishments are completed and the onsite meters are implemented, and their functionality is verified within the developed monitoring concept, a real data monitoring will be possible. The various KPIs will be then calculated for different time scales. In particular, the KPIs on building energy saving and related CO2 reduction will be calculated based on the energy consumption data measured after refurbishment compared with the previously presented historical one that serve as benchmarking data. As presented in Table 2 the annual energy saving by building efficiency measure will reach about 4760 MWh. The total installed RES capacity for electricity and heat will reach 145 kW and 178 kW, respectively. The resulting energy generation by RES will reach annually about 451 MWh. The resulting annual CO2 reduction (arising from fossil fuel saving and substitution) will amount to 1423 tCO2, distributed to 90% and 10% for building efficiency and RES measures, respectively. The calculation of the CO2 reduction resulting from the electricity and heat saving are performed based on the emission factors for Austrian electricity mix and the emission factors of the Vienna heat suppliers KELAG and Wien Energie (UMBA, 2018), (OIB, 2016), (Wien Energie, 2015).

Table 2: Estimated energy saving and CO2 reduction by building

KPI	Unit	Hauffgasse	Lorystr.	Herbortgass	NMS Enkplatz	Total building
Refurbished floor area	m^2	53,532.00	8,800.00	2,728.00	3,800.00	68,860.00
Energy savings by building efficiency measures	MWh/a	3,771.86	669.20	263.69	55.37	4,760.12
Specific energy saving by building measure	kWh/m^2. a	70.46	76.05	96.66	14.57	69.13
Final energy covered by RES	MWh/a	79.89	7.36	-	363.92	451.17
CO2 reduction by energy efficiency measures	tCO2/a	882.45	290.21	82.17	37.26	1,292.09
CO2 reduction by RES supply measures	tCO2/a	19.81	1.82	-	109.95	131.58
Total CO2 reduction for buildings	tCO2/a	902.26	292.03	82.17	147.21	1,423.67

5 CONCLUSION

For monitoring the impacts of the implemented integrated smart solutions of the Smarter Together Vienna LHC, an integrated KPIs-based monitoring process has been established supported by a co-creation process covering cities key stakeholders and covering the whole process of automated data collection, transfer to the city DMP and the subsequent processing and calculation of KPIs. The established concept covers the different steps of the monitoring process including the implementation of the meter infrastructure and the generation of desired KPIs related to the smart solutions being under implementation in the Vienna demo site projects. Within this effort following activities and main results have been achieved:

- Processing the historical data of building energy consumption and comparing the measured data with the related EPCs beside inter-comparison between the three residential buildings.
- Establishing the meter concept and defining the stakeholders involved in the monitoring process (from the data collection up to the storage on the data management platform and the final data processing for visualization and calculating the KPIs
- Calculation of selected KPIs regarding energy saving, renewable energy supply (RES) contribution and CO2 reduction based on the EPCs before and after the refurbishment. Once the post-refurbishment data are available, the real KPIs will be calculated using the reference data (historical data) before refurbishment.
- The achieved initial results for the main KPIs of buildings refurbishment indicate the following:
  - Energy saving by building efficiency measures will reach annually about 4,760 MWh/a.
  - The installed onsite capacities of PV will reach 145 kW, and that of solar thermal and heat pumps about 178 kW. The resulting annual fossil fuel saving through RES contribution will reach about 451 MWh/a.
  - Total annual fossil fuel saving through energy saving and RES measures will attain about 5,173 MWh/a and the resulting annual CO2 reduction of about 1423 tCO2/a
  - Specific energy saving per floor area will reach 69 $kWh/m^2.a$ and the specific CO2 reduction per floor area about 20.7 kg-CO2/ $m^2.a$.

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