3.3.1. CROSS-BORDER CASE STUDIES - MONITORING DRIVEN REHABILITATIONS

1. ESMES Project

The “Energy Smart Mediterranean School Network” (ESMES) project is one of the 41 projects funded by the European Neighbourhood Instrument (ENI), the largest multilateral initiative for cross-border cooperation (CBC) in the Mediterranean area - ENI CBC MED Program. The Program has a budget of €209 million, and is managed by the Autonomous Region of Sardinia (Italy). Creation of innovative start-ups, development of Mediterranean-wide economic value chains, diversification of tourism, technological transfer, inclusion of women and NEETS in the labour market, better management of waste, water and coastal areas, and improvement of energy efficiency in public buildings are the main challenges addressed by the 41 projects selected for funding in the framework of the first call for standard projects out of 439 project proposals submitted. The value of the 41 projects is €110 million, of which €100 million are of EU contribution.

ESMES addresses the issues of growing energy demand, fossil fuel dependence and increasing CO_2 emissions in the Mediterranean area. ESMES tackles the common challenge of fostering renewable energies and reducing energy use, with the common perspective of: adapting to Mediterranean climate conditions, finding innovative, effective ways of optimizing renovation investments and reducing the effects on the electricity network.

ESMES is implemented in five Mediterranean countries, involving five partner organizations, in addition to the beneficiary Institute for University Cooperation (ICU): the German Jordanian University (GJU), the Lebanese Center for Energy Conservation (LCEC), the National Agency for Energy Management of Tunisia (ANME), the Ribera Consortium of Valencia (CRIB), and the Alcamo Municipality in Italy (Alcamo).

The goal of this document is to exhibit various case studies of enhanced energy rehabilitation in schools based on the Project’s previous work and experience.

2. Case Studies’ Methodology

Across the Project’s countries of intervention, the Project has supported schools and educational institutions in enhancing their energy rehabilitation.

As part of its support to these schools, the Project:

- Piloted an innovative energy diagnosis methodology that relies upon building operating consumptions in real-life conditions, as well as the building’s designated use and energy analysis procedures, integrating them with evidence from energy audits;
- Piloted a monitoring-driven rehabilitation approach based on evidence from the energy diagnoses to develop energy rehabilitation plans using renewable energy and energy efficiency (REEE) interventions; and
- Demonstrated the cost-effectiveness and replicability of REEE solutions and SEM measures according to school rehabilitation plans through the installation and evaluation of the impact of REEE solutions on building energy performance.

The underlying methodology for realizing these outcomes includes:

- Selecting schools within the target communities that have non-linear energy loads;

- Establishment and training of “Energy Teams” within each school, which serve as the school “expert” body to conduct practical monitoring of energy consumptions using smart meters, collect weather data, and realize sustainable behaviors to achieve energy savings;
- Monitoring of energy consumption of the selected public schools in real-life conditions for around 12 months through smart meters and weather stations data collection (by the Energy Teams and supervised by the Project Partner) in order to provide baseline data for planning REEE interventions;
- Carrying out energy audits that consider building structure and forecast consumptions to serve as a basis to elaborate an innovative energy diagnosis that also considers buildings operational consumptions in real-life conditions through data collected from the aforementioned monitoring system;
- Development of energy rehabilitation plans for each school, which would serve as basis to install and pilot tailored REEE solutions;
- Providing subgrants to other schools with linear energy loads to realize REEE interventions;
- Designing optimized and customized PV systems designed through an innovative methodology which also considers actual energy loads and consumptions behaviors;
- Installation of the REEE systems as per the energy rehabilitation plans;
- Piloting of the REEE solutions and SEM measures for around 10 months to have a significant time range to monitor and assess effectiveness on energy and costs savings, as well as CO_2 reduction;
- Knowledge-sharing and elaboration of the pilots between all involved stakeholders to learn from each other’s experiences, outcomes, and challenges;
- Release of energy performance certificates to the rehabilitated schools following the performance of a post-energy audit and energy diagnosis to measure impact;
- Sharing of experiences and lessons learnt among schools within each country.

While these overarching outcomes and outputs were shared by the various countries of intervention, the approach taken to achieve them differed from one country to another (i.e. from one Project Partner to another Project Partner). Nonetheless, results were achieved through the involvement of school buildings end-users (students, headmasters, teachers), cooperation and mutual technical support among all Project Partners, and the application of each Project Partner’s role based on their specific competencies and expertise. It is worth noting that such roles were developed to ensure Cross-Border Cooperation (CBC) and seamless Project implementation, formalized through the development of a CBC Framework, which was composed of four thematic committees, reflecting the main themes related to energy policies and rehabilitations management in schools’ buildings relevant to the Project. These four thematic committees were: a) school policies; b) energy policies; c) technical solutions elaboration for REEE interventions in buildings; and d) implementation of REEE solutions. The committees were constantly engaged in a joint work, sharing ideas and know-how, and building innovations while learning from each other.

With such role distribution, six cross-border case studies on REEE project portfolio solutions for enhanced energy rehabilitation in school buildings are delivered. Each case study has been assigned to a Project Partner based on its expertise as per the CBC framework. The six case studies are namely:

- Monitoring driven rehabilitations (GJU);
- SEM measures (ICU);

- REEE solutions: custom design (CRIB);
- Investment planning through solutions portfolio approach (LCEC);
- Policy and financial support for REEE rehabilitations (ANME);
- Methodology: schools' involvement (Alcamo).

3. **Scope of the Document (**Monitoring Driven Rehabilitations)

This case study is focused on the Project Partners' effort in developing school building rehabilitation plans using REEE interventions to reduce energy consumption and increase renewable energy share using a monitoring-driven rehabilitation approach. In developing rehabilitation plans, the Project utilized evidence from various innovative energy diagnoses such as building operating consumptions in real-life conditions, the building's designated use and energy analysis procedures, and evidence from energy audits.

4. Project Partners Project Experience

a) Jordan Pilots

<u>Monitoring Driven Rehabilitations</u>

In coordination with the Ministry of Education, the Project Partner in Jordan (GJU) considered nine schools for its REEE rehabilitation interventions. These schools represented different climatic zones in Jordan and vulnerable communities. Ultimately, four schools were supported by the Project in the development of monitoring driven rehabilitation plans: three schools were selected based on their non-linear energy loads, whereas the fourth school won the Project's school subgrant contest (i.e. standard school), awarding it REEE rehabilitation support. The four schools were namely:

- Jrainah Technical School for Boys in Madaba Governorate
  - Has a baseline energy consumption of 9.4 kWh/m^2.
  - The school building includes 12 classrooms, 4 technical workshops, 3 laboratories, and several administrative rooms and other facilities.
  - The building's typical occupancy is for 214 school days.
  - The school uses 20 kerosene heaters to heat up the classrooms and staff areas for a limited duration during the day, and only during very cold days (there is a limit of 1500 liters of kerosene supplied to the school by the Ministry of Education yearly). The current heating system for the school is not enough to reach comfort levels on all winter days.
  - The school uses 15 small fans to provide some cooling during the hot months. The provided cooling by the fans is reported to be insufficient in the hot days.
  - The school uses a variety of fluorescent and LED lights, having had some relatively recent renovation to the lighting fixtures. However, the current light distribution and intensity is not acceptable, and produces very low lux levels in most areas including most classrooms. The current lights are mostly very poor quality and need replacement. The school's lighting design and fixtures distribution is not acceptable for school activity, having around 70-200 lux in classrooms, labs, offices, and most workshops even when there is some ambient light.
  - The windows are composed of clear, single-pane glass in an aluminum frame.
  - The external walls are made of concrete clad walls. All walls have no insulation.
  - The roof is constructed using reinforced concrete with a tar waterproofing layer.

- Bait Yafa School for Girls in Irbid Governorate
  - Has a baseline energy consumption of 6.7 kWh/m^2.
  - The school building includes 26 classrooms, four laboratories, three workshops, and several administrative rooms and other facilities.

  - The building's typical occupancy schedule is from 7:40 a.m. to 2:00 p.m. on weekdays (205 school days).
  - The available cooling system is not sufficient to reach comfort levels, especially in the classrooms on the southern facade.
  - The school uses 1200 T8 fluorescent lamps for all lighting needs, except for a few incandescent lambs in the theater.
  - The current glazing system for the base case is made of a single layer of 6 mm clear glass, with aluminum frames without thermal breaks. The glazing system contains operable sliding windows and fixed windows.
  - The external walls used in the base case are made of 30 cm hollow blocks, covered by 2 cm of cement plaster from both sides. Both sides are painted.
  - The roof of the base case is made out of reinforced concrete, covered with a waterproof layer. The inner side of the roof is covered with cement plaster and painted.

- Madaba Technical School for Boys in Madaba Governorate
  - Has a baseline energy consumption of 4.2 kWh/m^2.
  - The school consists of 17 classrooms, 9 technical workshops, 3 laboratories, and several administrative rooms and other facilities.
  - The building's typical occupancy schedule is from 8:00 a.m. to 1:30 p.m. on weekdays (214 school days).
  - The school uses 45 kerosene heaters to heat up the classrooms and staff areas for a limited time during the day, and only during very cold days, due to a limit of 3000 liters of kerosene supplied to the school by the Ministry of Education yearly. In addition to the kerosene heaters, the school uses a small boiler and radiator system to heat up the theater and parts of the administration building, and consumes around 1500 liters of diesel a year.
  - The school uses air conditioning split units and ceiling fans for cooling.
  - The school mainly uses 120 cm and 60 cm T8 fluorescent lamps for most lighting needs, in addition to some incandescent bulbs, spotlights, and flood lights. The school's lighting design and fixtures distribution is acceptable for school activity,
  - Windows are of single, clear glazing with non-thermally broken aluminum frame.
  - The external walls are made of concrete hollow blocks (15 cm), with no insulation.
  - The roof is constructed using reinforced concrete with a tar waterproofing layer.

To commence the monitoring-driven rehabilitations approach, energy and thermal audits were carried out for each of the schools. This was done through several site visits, detailed measurements, load behavior observations, and system modeling and evaluation. Site visits were conducted to the schools to collect required information using site surveys and interviews with the school's administrative staff to collect data regarding energy usage durations, behavior, and habits to achieve the best estimation of unrecorded parameters. The purpose of the energy audit report was to assess the current energy status of the schools, collect more information on available cooling technologies/methodologies, and assess the suitability of the sites for receiving renewable energy and cooling interventions (i.e. electricity system, environmental conditions, etc.). Not only so, but the energy audit report suggested various renewable energy and cooling solutions for the various schools. The energy audit results served as a baseline for post intervention comparison.

Following the energy audits, thermal audits were also performed. The purpose of these thermal audits was to compare the energy consumption for the different schools under different cooling retrofitting scenarios (based on the results of the energy audit) and then estimate the cost for each scenario. This analysis allowed the project team to assess and optimize the cooling and renewable energy interventions based on intervention cost and energy savings and to see how the suggested interventions will lower the cooling load. As part of this analysis, both passive and active cooling solutions were assessed.

To collect additional evidence for a thorough energy diagnosis that would ultimately lead to the development of suitable energy rehabilitation plans using REEE interventions, schools were equipped with smart meters to track their energy consumption for 12 months. The Project Partner designed and managed an online platform that was linked to schools' smart meters to track/compare and publish energy consumption trends. Data analysis and data acquisition systems were used to carry out monitoring-based REEE tasks such as data logging and monitoring technologies that assist in the analysis of a variety of transient school events and load behaviors. Such monitoring of energy consumption in real-life conditions is done in order to provide baseline data for planning REEE interventions, as well as provide a better understanding of the load behavior.

To ensure that school stakeholders take ownership of the rehabilitation efforts and that the rehabilitation plans are responsive to the needs of the schools and are suitable to the context, the project has worked hand-in-hand with headmasters, teachers, and students at the schools. The Project established "Energy Teams" at each school, which became in charge of monitoring the schools' energy consumption and realizing sustainable behaviors to achieve energy savings. The Energy Team was initially trained on project objectives, practical monitoring of energy consumptions through smart meters, weather collection data, and sustainable behaviors to achieve energy savings. The team was composed of the headmaster, two teachers, and 10 students, chosen among students of all years by the headmaster.

Using the comprehensive information collected, a data-driven design approach was applied utilizing location-specific, environmental, and energy data from the schools to design tailored PV systems in accordance to the unique needs, conditions, and consumption behaviors that these sites present. In Jordan, the typical design approach involves the utilization of 1560 kWh/kWp/year or 4.3 kWh/kWp/day as a factor to size PV systems, while adhering to utility company limitations. In this report, the approach followed is a data-driven design procedure. Weather, energy, and location data were utilized as inputs to support the design process. The procedure relies on mathematical modeling as a way to predict and optimize PV system performance based on specific inputs and conditions. The mathematical modeling procedure determines the minimum PV system size required to fully meet the annual electrical energy demand of the schools, while taking into consideration environmental and consumption input parameters.

The load at some of the schools due to the nature of the machinery and equipment being operated is non-linear. Such irregularities impact the electrical system voltage and current, which in turn impose consequences on the electricity grid (e.g. power quality, grid stability) and on the PV system inverters. Not only does the power quality of the school grid suffer, but also the power quality of the neighboring establishments. Additionally, the load profile would cause interruptions in the inverters' operation, thus reducing energy generation from the PV system. Therefore, solutions to support and protect the grid, offer improved grid stability, protect the PV system inverter, reduce its shutdown, and thus increase energy generation were recommended. Such solutions included automatic voltage regulators (AVR), power factor compensators (PFC), power plant controllers, and hybrid on-grid inverter coupled with a battery storage system.

Based on the data collected through the above outlets, energy rehabilitation plans were developed for each school, which served as a basis to install and pilot tailored REEE solutions. The plans focused on energy-consumption-intensive components and intended to diversify and distribute interventions across a sizable number of buildings, while maximizing energy savings impact in target areas. They were tailored and optimized to the schools' actual energy consumption, load patterns and electrical properties, equipment features, expected impact (saved kWh, reduced costs and CO_2), climate conditions, and technology maturity.

Based on the carried out energy diagnoses, the following interventions were deemed necessary to achieve energy savings and introduce REEE technologies that were responsive to the true needs of the schools:

- Jrainah Technical School for Boys in Madaba Governorate
    - On-grid photovoltaic system
    - Window maintenance

- Bait Yafa School for Girls in Irbid Governorate
    - On-grid photovoltaic system
    - Inverter air conditioning units
    - Ceiling fans
    - Window maintenance

- Madaba Technical School for Boys in Madaba Governorate
    - On-grid photovoltaic system
    - Hybrid on-grid inverter
    - Battery storage system
    - Automatic voltage regulator (AVR)
    - Power factor compensator (PFC) solution

b) Italy Pilots

Monitoring Driven Rehabilitations

The Project Partner in Italy (Municipality of Alcamo) supported one school in the development of a monitoring driven rehabilitation plan – S. Bagolino Middle School. This school had a standard load and had communicated its need to reduce its energy consumption.

At first and in order to gain a solid understanding of the electrical energy profile of the school's consumption, the Project Partner contracted a specialized company for the supply, installation, and maintenance of six multimeters (with a 12-month warranty) to monitor the electrical consumption of the school and transmit the data to the Project's online platform. Such monitoring served as a basis for the design of the FTV system and to sensitize the school community on consumption. The school's consumption was monitored for 550 days.

It was observed that the school's electricity consumption amounted to 35.61 MWh during the monitored period. Therefore, in order to considerably cut down on electricity consumption, a photovoltaic system and outdoor lighting re-lamping were considered. The Project Partner's funds permitted the rehabilitation of the school without an energy diagnosis. Therefore, it was decided to proceed with the installation of a photovoltaic system and a re-lamping of the outdoor lighting, entrusting the related design to a specialized professional. Subsequently, the work was entrusted to the company CIM of Alcamo that was also specialized in photovoltaic installations. The interventions identified represented the most virtuous interventions; i.e., interventions that provide the greatest energy savings relative to investment costs based on the affordability by the Project.

A photovoltaic system is to be installed on the roof of the school building, which would allow the saving on energy consumption and production of green, sustainable energy. Additionally, the design was made in a way that is compatible with architectural or environmental protection requirements (e.g. visual impact). The amount of electricity that can be produced on an annual basis by the planned photovoltaic system is estimated on the basis of radiometric data for the locality of Trapani, contained in UNI10349. Given the geographical location of Trapani, the average annual irradiation on the plane of the modules, the transformation efficiency, and the monitoring of similar plants operated in the area, the average annual electrical energy production over the next 20 years from the photovoltaic system is estimated to be:

Energy generated the first year: 1500 (kWh/year) x 15.6 (kWp) = 23,400.00 kWh/year

Average annual generated energy over the twenty years: 1500 (kWh/year) x 15.6 (kWp) x 0.9= 21,060 kWh/year.

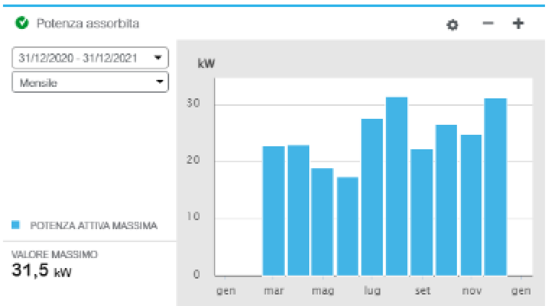
The school, on the east-facing external slope, has a general outdoor recreational and service area. It is completely devoid of artificial lighting and one goal was to light this area using floodlights made of die-cast aluminum, installed at an average height of nine meters above the ground and equipped with a LED source of new generation, photometric optics of asymmetrical type, suitable for large areas and color temperature of 4000 °K (natural light).

It is noteworthy to mention that the school was engaged throughout the planning for these interventions. In addition, the school itself aimed at raising the school community's awareness of energy conservation (meetings, contests, and approval of educational pact).

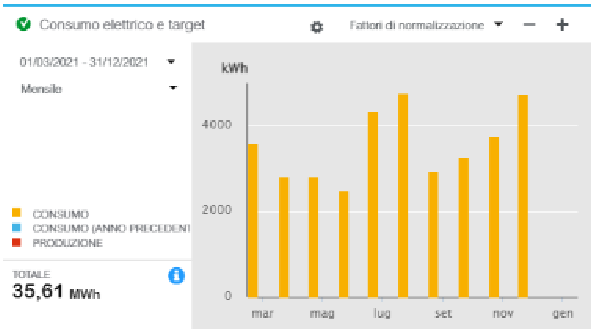
S. BAGOLINO COMPREHENSIVE INSTITUTE

Energy performance chart comparing schools

Energy efficiency chart Bagolino school



School power input graph Bagolino



School electricity consumption graph Bagolino

c) Spain Pilots

<u>Monitoring Driven Rehabilitations</u>

The Project Partner in Spain (CRIB) supported two schools in the development of monitoring driven rehabilitation plans. One school was selected due to its non-linear energy load, whereas the second school had a standard load. The two schools were namely:

- IES Bernat Guinovart
    - A public educational center located in the city of Algemesí offering compulsory secondary education (12-16 years of age) and non-compulsory secondary education (16-18 years of age). It additionally provides vocational education such as electricity and electronics, robotics, and mechanical manufacturing formative specialities.

  - According to statistics collected in 2019, IES Bernat Guinovart has 705 students (57% males and 43% females) and 80 school staff.
  - Has a non-linear energy load.
  - Has a baseline energy consumption of 22.4 kWh/m^2 (80 kWh/student).
  - Has a total final energy consumption of around 102,613 kWh (electricity: 56,174 kWh; heating by a diesel-oil boiler: 46,464 kWh).
  - The 2019 school electricity consumption per system was distributed as follows: 24,099 kWh for lighting, 18,000 kWh for heating and cooling, 8,450 kWh for IT equipment, 2,800 kWh for the workshops' electrical motors, and 2800 kWh for other equipment.
  - The school's five buildings include 44 classrooms, 2 workshops, 1 sports hall, and communal spaces.
  - The school is open all year round from 8:00 a.m. to 9.00 p.m. except in August.
  - All classrooms have a heat pump system.
  - The existing lighting system included different technologies such as LED lamps and fluorescent lamps/tube.
  - The buildings' constructive features include: joist and concrete vault on hanged beams, brick wall with wall cavity (no insulation), ventilated roof, sloping, and partition walls on the first-floor ceiling with no insulation.
- CPEE Miquel Burguera
  - A special education center in Sueca that offers its students comprehensive training to promote the development of the five human capacities: cognitive, psychomotor, personal development (in all areas), interpersonal relationships, and social insertion in order to achieve the well-being of the student, maximum autonomy, and active participation in society.
  - Serves 120 students and has a staff body of 80 individuals.
  - The baseline electrical energy consumption is 74,262 kWh.
  - The electricity consumption per system is distributed as follows: 21,960 kWh for lighting, 12,155 kWh for heating and cooling, 2,859 kWh for appliances, and 37,297 kWh for other equipment, services, and heating radiators.
  - The center has one main building composed of classrooms, common areas, a library, canteen, and offices, in addition to various outdoor areas for activities and sport facilities.
  - The center has a pellet boiler for heating the main building, but it does not operate properly. Multiple heat pumps were installed to make up for the ineffectiveness of the pellet boiler.
  - The lighting system is composed of 50% LED lighting and 50% fluorescent and halogen technology.

The selection process of the schools was done as follows. IES Bernat Guinovart was selected based on its non-linear load. As for CPEE Miquel Burguera, a call for proposals was launched by the Project Partner addressing city councils seeking energy rehabilitations at a public school within their territories based on a previously conducted energy audit or diagnosis. City councils submitted rehabilitation proposals focused on the components with the highest energy consumption and/or CO_2 emissions, while ensuring that the subsidized interventions are replicable. The ultimate goal was to improve the sustainability of a public school building based on the increase of building energy efficiency and the installation of sustainable energy sources. Based on this criteria, the Project Partner chose the rehabilitation plan of the city of Sueca.

Based on engagement with the school body, the following goals were highlighted for each of the schools:

- IES Bernat Guinovart
  - To reduce the energy consumption of the school;
  - To cover the school's electricity demand with renewable energy solutions; and
  - To improve the comfort of building users.

- CPEE Miquel Burguera
  - To improve the energy sustainability of the center; and
  - To install renewable energy solutions and ultimately contribute to the energy independence of the Sueca territory and its reduction of petroleum importation for energy generation.

To begin the monitoring-driven rehabilitations approach, a complete energy audit for IES Bernat Guinovart was carried out by the Project Partner. Additionally, for CPEE Miquel Burguera, an energy diagnosis was submitted by the Sueca City Council to support the Project's efforts. The purpose of these studies is to provide thorough data and information on the institutions' baseline and historical energy consumption and its nature, existing technologies, and adaptability of innovative solutions.

To collect additional evidence for a thorough energy diagnosis that would ultimately lead to the development of suitable energy rehabilitation plans using REEE interventions, a smart meter was installed by the Project Partner at IES Bernat Guinovart and consumption was monitored for 18 months. The historical energy consumption at CPEE Miquel Burguera was analyzed to identify patterns. Monitoring of energy consumption in real-life conditions at IES Bernat Guinovart was done in order to provide baseline data for planning REEE interventions, as well as provide a better understanding of the load behavior.

To ensure that school stakeholders take ownership of the rehabilitation efforts and that the rehabilitation plans were responsive to the needs of IES Bernat Guinovart and were suitable to the context, the project worked hand-in-hand with the headmaster, two teachers, and 10 students chosen by the headmaster across all years. This became known as an "Energy Team," which became in charge of monitoring the schools' energy consumption and realizing sustainable behaviors to achieve energy savings. The Energy Team was initially trained on project objectives, REEE guidelines, practical monitoring of energy consumptions through smart meters, weather collection data, and sustainable behaviors to achieve energy savings. The Energy Team also contributed to the definition of the school energy rehabilitation plan by proposing REEE measures based on the energy audit previously carried out by the Project Partner. As for CPEE Miquel Burguera, the school managerial board and the Sueca city council were mainly responsible for supporting the development of the rehabilitation plan and other investment propositions.

Based on the data collected through the above outlets, energy rehabilitation plans were developed for each school, which served as a basis to install and pilot tailored REEE solutions. The plans focused on energy-consumption-intensive components and intended to diversify and distribute interventions across a sizable number of buildings, while maximizing energy savings impact in target areas.

They were tailored and optimized to the schools' actual energy consumption, load patterns and electrical properties, equipment features, expected impact (saved kWh, reduced costs and CO_2), climate conditions, and technology maturity.

Based on the carried out energy diagnoses, the following interventions were deemed necessary to achieve energy savings and introduce REEE technologies that were responsive to the true needs of the schools:

- IES Bernat Guinovart
- CPEE Miquel Burguera

a) Tunisia Pilots

<u>Monitoring Driven Rehabilitations</u>

The Project Partner in Tunisia supported one university and nine schools in the development of monitoring driven rehabilitation plans. Specifically, the institutions were supported in developing REEE focused rehabilitation plans.

The selected schools are relatively old and do not have any energy efficiency measures or modern heating and cooling systems. Also, the highest share of their energy consumption was for lighting, which is typical for older buildings that were not designed with energy efficiency in mind. In terms of energy use, an average of 5 kWh/m² is consumed for schools and 45 kWh/m² for the university.

Reducing energy bills is the highest need for these institutions. The Project Partner considered a range of energy efficiency measures, including replacing older lighting fixtures with more energy-efficient LED lights, as well as implementing PV plants.

To begin the monitoring-driven rehabilitations approach, a complete energy audit was conducted for the university over three phases. A preliminary audit was carried out to identify energy consumption patterns and potential savings opportunities. This was followed by a detailed audit in the second phase, which involved a comprehensive analysis of the university energy systems and equipment, energy consumption patterns, and potential energy efficiency measures. The proposed measures were implemented and the energy consumption of the university was monitored to assess the impact of the measures on energy efficiency and cost savings.

The energy consumption was monitored for a year through the installation of smart meters and data loggers. These devices collected data on energy usage durations, behavior, habits, and other factors in real-time. The data was then analyzed to provide a baseline for planning REEE interventions.

As for the schools, the Project Partner conducted a simple diagnosis based on observations and energy bills' analysis for a year. Additionally, surveys were conducted and school staff was engaged to understand their energy usage patterns and behaviors.

To involve the school community, the Project Partner organized workshops and training sessions for school administrators, teachers, and staff to raise awareness about the importance of energy efficiency and sustainable practices. Students were also involved in the project, through activities such as energy audits and awareness-raising campaigns. In addition, the Project Partner worked closely with school administrators and teachers to develop energy-saving plans and identify areas for improvement.

Ultimately, the rehabilitations that the Project Partner recommended based on the comprehensive energy diagnoses conducted were electrical rehabilitations, implementation of building technical management, and relamping.

b) Lebanon Pilots

<u>Monitoring Driven Rehabilitations</u>

The Project Partner in Lebanon (LCEC) supported seven schools in the development of monitoring driven rehabilitation plans. Two schools were selected due to their non-linear energy load, whereas the remaining schools had a standard load. The schools were namely:

- Amir Shakib Erslan Mixed Public Secondary School
    - Has a baseline energy consumption of 4,376,800 kWh/month.
    - The student body is 1,246 students, occupying 10 floors.
    - The buildings are made of concrete walls and concrete roof with insulation membrane finishing.
    - The windows are single glazed with aluminum frames.
    - The heating and cooling system utilize AC split units in administration offices and regular ceiling fans in classrooms.

- Majadel Public School
    - Has a baseline energy consumption of 600 kWh/month (0.53 kWh/m^2).
    - The student body is 728 students, occupying four floors.
    - The buildings are made of concrete walls and concrete roof with insulation membrane finishing.

    - The windows are single glazed with aluminum frames.
    - The cooling system utilizes AC split units in administration offices and regular ceiling fans in classrooms.
    - The heating system utilizes gas heaters.

- Barouk Public School
    - Has a baseline energy consumption of 500 kWh/month (0.63 kWh/m^2).
    - The student body is 108 students, occupying three floors.
    - The buildings are made of concrete walls and concrete roof with pebble finishing.
    - The windows are single glazed with aluminum frames.
    - There is no cooling system.
    - The heating system utilizes fuel boilers.

- Ecole Officielle Hosh El Omara
    - Has a baseline energy consumption of 3,300 kWh/month.
    - The student body is 288 students, occupying four floors.
    - The buildings are made of concrete walls and concrete roof with insulation membrane finishing.
    - The windows are single glazed with aluminum frames.
    - The cooling system utilizes AC split units in administration offices and regular ceiling fans in classrooms.
    - The heating system utilizes fuel boilers.

- Ain Jarfa Intermediate Public School
    - Has a baseline energy consumption of 420 kWh/month (0.93 kWh/m^2).
    - The student body is 341 students, occupying four floors.
    - The buildings are made of concrete walls and concrete roof with insulation membrane finishing.
    - The windows are single glazed with aluminum frames.
    - There is no cooling system.
    - The heating system utilizes fuel boilers.

- Ecole des Arts et Métiers
    - Has a non-linear energy load.

- Hassan Vocational and Technical Education Complex
    - Has a non-linear energy load.

To begin the monitoring-driven rehabilitations approach, a walk-through energy audit was initially conducted for each of the schools. The Project Partner noted the energy consuming appliances and the patterns of usage along with the readings taken from the installed energy meters. Following such, a full energy audit with exact measurements was conducted by an energy service company, which delivered several reports (baseline report, findings, and recommendations. The energy audit's methodology included the following set of tasks:

- Gathering historical utility bills;
- Gathering facility layouts, descriptions, load data, and operational hours;
- Undertaking an in-depth field survey and audit covering all sections, utilities end uses of the facility, load inventory, equipment status, operational performances;
- Performing the needed real time measurements and data logging;
- Building an energy simulation of the facility using energy analysis software, allowing the Project Partner to establish a detailed load and cost breakdown (energy balance), as well as an in depth study on the consumption of the facility;
- Investigating potential energy efficiency measures (EEMs) from the low cost/no cost ones to those with low CAPEX and quick returns and then those with higher CAPEX and longer returns;
- Developing the chosen EEMs with their impact on the energy consumption and related financials;

- Preparing a comprehensive report that would be divided into two main parts and the appendixes:
    - In depth analysis of the present situation including utilities analysis, energy baseline, energy balance, and detailed systems description;
    - EEMs: technical analysis, savings development, and financial analysis;
    - Appendixes: full load inventory list.

Since the energy audit was performed during the COVID-19 pandemic and schools were not operating in-person at that time, EDAM's load inventory data was entered in the energy analysis system including: assets name/category, actual electrical specification (kW), and operational schedule over 12 months (hours per day, week, month or season). The second step was performing an energy simulation as per the methodology previously described. It should be noted that due to the COVID-19 pandemic and the consequent shutting down of schools, as well as the ongoing economic crisis in Lebanon, the public went on strike for several months, preventing the Project Partner from monitoring actual consumption in real time for long periods of time during the energy audit.

The micro and macro energy consumption analysis of energy systems including lighting, heating, air conditioning, ventilation, and building envelope, served the purpose of identifying where and how the facilities use energy. The breakdown of the energy consumption by end-use would be the energy balance, which provided an important baseline for the roadmap in developing the EEMs that would optimize the overall energy costs.

Through such a thorough analysis, it was concluded that the lighting systems at all schools had the highest load percentage of 44%. Therefore, retrofitting all existing incandescent/fluorescent lamps with LED lamps would decrease the school energy consumption by more than a half.

To ensure that school stakeholders took ownership of the rehabilitation efforts and that the rehabilitation plans were responsive to the needs of the schools, school administrations were contacted to better understand their energy needs and were part of the decision of retrofitting the lighting systems. The Project Partner also facilitated the formation of Energy Teams, which were provided with training by the LCEC team that explained the school's energy consumption patterns and ways to implement improved energy habits. The Energy Teams then disseminated this information to all their colleagues, peers, friends, and families.

5. Recommendation and Lessons Learned

a) Jordan

- Collecting long-term, comprehensive data from the sites where interventions are being planned for is crucial for the design of impactful and responsive solutions.
- It is important to engage the school body in developing energy action plans and in dialogue to increase energy efficiency within their practices as a way to foster ownership.
- Building good rapport and relationships with the school body limits barriers and facilitates seamless implementation of solutions.
- Engaging with students and staff is key to developing responsive solutions as these are the main stakeholder groups when it comes to implementing REEE interventions in schools.
- An energy audit of schools with high energy consumptions must be conducted as they serve as priority sites for REEE interventions.
- In planning and designing building REEE interventions, the building envelope should be examined, in addition to energy consumption levels and patterns.

b) Tunisia

- Collecting baseline data is necessary to understand the energy usage patterns of the buildings and identify areas for improvement.
- Continuous monitoring is essential to evaluate the performance of the implemented measures and to identify any issues that may arise.
- Raising awareness and capacity strengthening is critical to the success of the project. Occupants can provide valuable insights into building usage patterns and can help to identify areas for improvement.
- Financial incentives can encourage building owners to invest in energy efficiency measures.

c) Lebanon

- By encouraging the Energy Teams to monitor their consumption through the installed smart energy meters, the Energy Teams developed a better understanding of their energy patterns and considered ways to improve their energy habits. The monitored data could also be used for future energy rehabilitation plans.