EEG ENERGY SERVICES
Customer-Driven Energy Solutions

UNITED NATIONS DEVELOPMENT PROGRAM (UNDP)

Provision of Professional Services of Energy Audit Firm for the CEDRO IV Photovoltaic (PV) Sites LEB/CO RFP/24/14

Energy Audit Report for USEK

February , 2015

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Abbreviations Table

A	Amperage
AC	Air Conditioning
AHU	Air Handling Unit
Amps	Amperage
BMS	Building Management System
CAV	Constant Air Volume
CF	Compact Fluorescent
CO_2	Carbon Dioxide
COP	Coefficient of Performance ($KW_{cooling}/KW_{electrical}$)
ECG	Electricity Company of Ghana
EEM	Energy Efficiency Measures
ESCO	Energy Services Company
FAF	Fresh Air Fan
Fluo	Fluorescent
GHG	Green House Gases
Hal	Halogen
HVAC	Heating Ventilation Air Conditioning
IRR	Internal Rate of Return
KV	kilo Volt
KVA	kilo Volt Ampere
KW	Kilowatt
KWh	Kilowatt-hour
LED	Light Emitting Diode
M	Meter
m^2	Square meter
MDB	Main Distribution Board
MH	Metal Halide
°C	Degree Celsius
°K	Degree Kelvin
°F	Degree Fahrenheit
PF	Power Factor
TR	Transformer
UPS	Uninterruptible Power Supply
V	Volt
VAV	Variable Air Volume

VFD	Variable Frequency Drive
W	Watt
W m²/ °K	Watt Square meter per degree Kelvin

Conversion Factors

Multiply	By	To Obtain
Meter	3.2808399	Feet
Meter	39.370079	Inches
Kg	2.2046226	Pounds
Tons	1000	Kg
Liter	0.264179	Gallons (US beer)
Liter	0.035315	Cubic feet
kWh	3.6	MJ
kWh	3412	BTU
W/m^2	0.317	BTU/ft^2
kJ/kg K	0.2388	BTU/lb °F
W (heat flow rate)	3.412	BTU/h
W/m^2k	0.1761	BTU/ft^2 h °F
kJ/kg	0.4299	BTU/lb
MJ/m^3	26.84	BTU/ft^3
Mm Hg (mercury)	133.332	Pa
Ft of water	2.98898	kPa
m^3/kg	16.02	ft^3/lb
m/s	3.281	ft/s

1. Introduction

Following an agreement with the UNDP/CEDRO contract # 14/125, *Energy Efficiency Group (EEG)* has undertaken an energy audit for USEK, Kaslik.
The property includes 12 faculties, 4 institutes, administration offices and dorms spread over nine buildings. USEK has an annual energy budget in excess of $535,806 including electricity and diesel for generators.
The energy audit was carried out in October-December 2014 by a combination of a field in depth survey and additional offices analysis; a close coordination and cooperation was made with the administrative team in the building.
The report is divided in two sections: the first one provides the detailed analysis of the present energy infrastructure including the energy accounting, load description and breakdown, and while the second provides the development of the proposed EEMs (Energy Efficiency Measures) including their technical analysis and financial feasibility.

1.1. Energy Audit procedure

The energy audit evaluates the efficiency of all buildings that use energy. The energy auditor starts at the utility meters, locating all energy sources coming into a facility. The auditor then identifies energy streams for each gas, quantifies those energy streams into discrete functions, evaluates the efficiency of each of those functions, and identifies energy and cost savings opportunities.
An energy audit serves the purpose of identifying where a facility uses energy and identifies Energy Efficiency Measures (EEM).

The goals of the energy audit are:

- To clearly identify the types and costs of energy use.
- To understand how the energy is being used – and possibly wasted.
- To identify and analyze various EEM alternatives such as improved operational techniques and/or new equipment that could substantially reduce energy costs.
- To perform an economic analysis on those alternatives and determine which ones are cost effective for the business or industry involved

The energy audit is done following the below set of tasks:

1. Gathering all historical databases from Energy Bills.
2. Gathering all facility layout, description, load data, operational hours.
3. Perform a full load inventory on all electrical loads from lighting to HVAC, motors, resistive equipment…
4. Perform real time and historical measurement (Data logging) on all important electrical loads and distribution panels.
5. Build an Energy Simulation of the facility using Energy Analysis software. This modeling will allow us to have a detailed load and cost breakdown (Energy balance) along with an in depth study on the consumption of the facility.
6. Investigate 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.
7. Develop the chosen EEMs with their impact on the energy consumption and related financials
8. Prepare a comprehensive report that would be divided into 3 main parts:

a) Detailed analysis of the present facility's energy status including energy analysis, energy balance, detailed systems description…
b) EEMs : Technical analysis, savings development, financial analysis
c) Appendices: Full load inventory list and any supporting technical documentation.

2. USEK General description and information

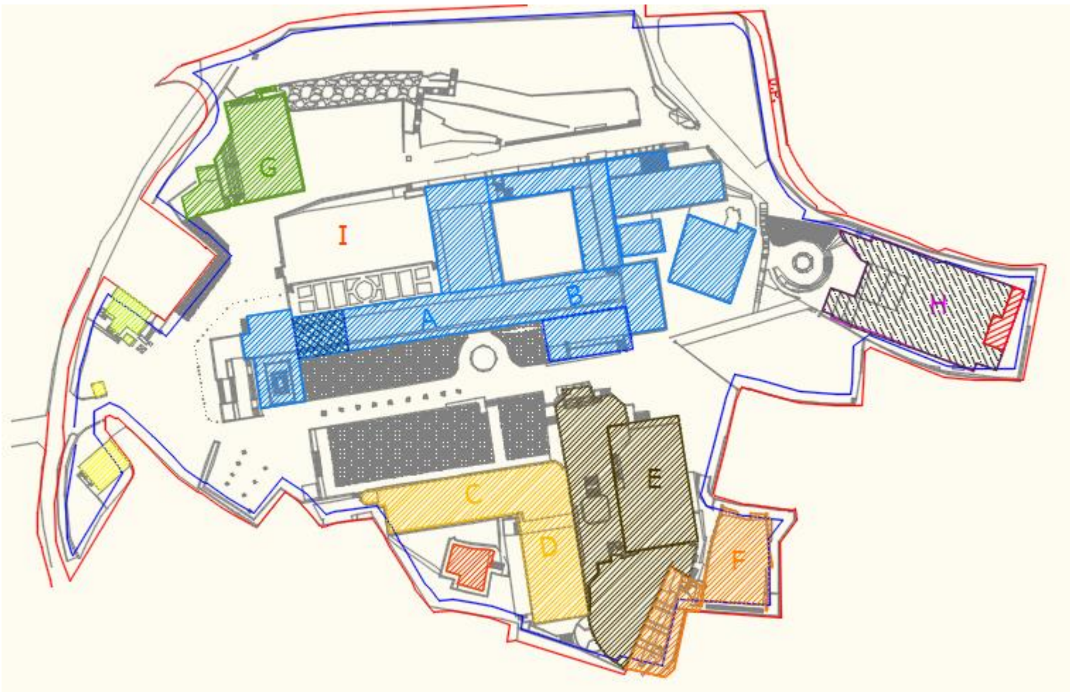
2.1. Facility General description

The Holy Spirit University of Kaslik located near the bay of Jounieh, includes12 faculties and 4 institutes along nine blocks as listed hereafter:

- **Building A:** Office of the President; the Main Library; Pontifical Faculty of Theology; Institute of History; Institute of Liturgy; Faculty of Music.
- **Building B:** Faculty of Law; Faculty of Letters; Faculty of Philosophy and Humanities.
- **Building C:** Faculty of Fine and Applied Arts.
- **Building D:** Faculty of Business.
- **Building E:** Faculty of Agriculture and Food sciences; Higher Institute of Political and Administrative Sciences.
- **Building F:** Students Dorms.
- **Building G:** Administrative and Technical Units.
- **Building H:** Faculty of Engineering; Faculty of Medicine and Medical Sciences; Faculty of Sciences; Higher Institute of Nursing Sciences.
- **Building I:** Sports center. This center is located in an underground floor next to the basket ball court.

You will find here below the USEK campus layout map.

Figure 1: USEK Campus map



The facility has two entrances, the first gate passing through the oldest church of USEK and the second gate leading to an open air parking along four basements where students, professors and employees park their vehicles. Furthermore, there is an additional parking for students on the other side of the road.

Building G is a standalone one located outside the campus with some rented floors. Finally, USEK has one cafeteria located in between buildings E and C.

2.2. Facility Building Envelope

Because of its history, USEK campus is characterized by building with very different architecture and building envelopes. The main buildings of USEK which are blocks A and B feature a vernacular architecture of the 1950s with an external stone cladding of 80cm thickness providing a good insulation from outside temperature variations.

Buildings C, D, E and G have standard building envelope based on single wall with a related U-value of 2.53W/m^2.°C, single glazing having a U-value of 6 W/m^2.°C, lacking all kinds of insulation which increases potential heat gains.

As for the new constructed buildings H and F, a modern architecture is adopted with extensive use of glass areas and skylights allowing substantial daylight which reduces the usage of artificial lighting but raises also the cooling load.

Figure 2: Building envelope block A (Left); Skylights in block H (Middle); Single wall and single glazing in block C (Right)

Lebanon Key Climatic conditions

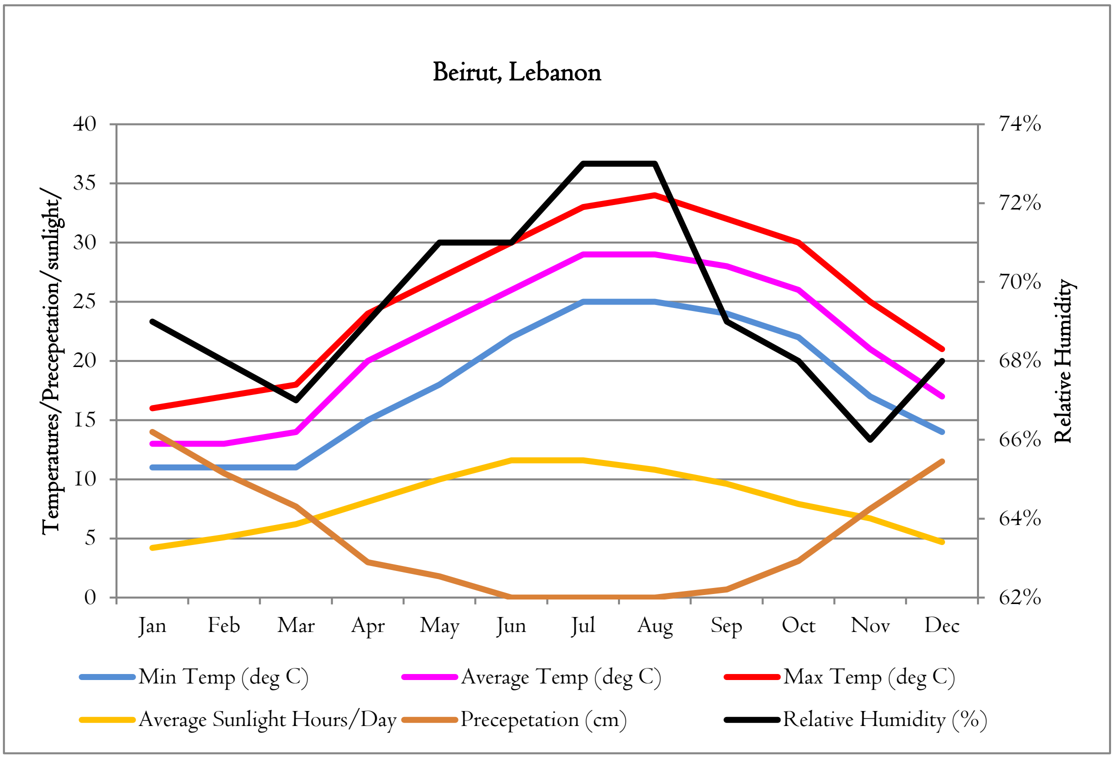
Climate conditions have the largest impact on energy consumption due to the related large HVAC loads affected for cooling or heating.

Lebanon has a Mediterranean climate - hot and dry in summer (June to August), cool and rainy in winter (December to February).

In summer humidity is very high along the coast and daytime temperatures average 30°C, with night temperatures not much lower. Winter is mild, with daytime temperatures averaging 15°C. In the mountains, summer days are moderately hot (26°C on average) and the nights cool. Winters are cold, with snowfall above 1,300m.

In spring (March to May) and autumn (September to November) the climate is warm but not uncomfortable.

You will find here below a graph depicting all the climate average trends in Lebanon.



- The average temperature in Beirut is 20.2°C
- The range of average monthly temperatures is 13°C.
- The warmest average max/ high temperature is 30°C in August.
- The coolest average min/ low temperature is 10 °C in January & February.
- Lebanon receives on average 601 mm of precipitation annually or 50 mm each month.
- The month with the driest weather is June, July & August when on balance 0 mm of rainfall falls occurs.
- The month with the wettest weather is January when on balance 140 mm of rain, sleet, hail or snow falls across 16 days.
- Mean relative humidity for an average year is recorded as 69.3% and on a monthly basis it ranges from 66% in November to 73% in July & August.
- Hours of sunshine range between 4.2 hours per day in January and 11.6 hours per day in July.
- On balance there are 2,940 sunshine hours annually and approximately 8.1 sunlight hours for each day.

2.3. Electrical Energy: Sources and Distribution system

The local utility EDL is the only electricity supplier. In addition, there are six 1,000 KVA generators and two 700KVA generators used as backup in case of power failure.
below is a table with the list of the key electrical distribution transformers and generators along a single line diagram of the connections.

Table 1: Installed generators and transformers

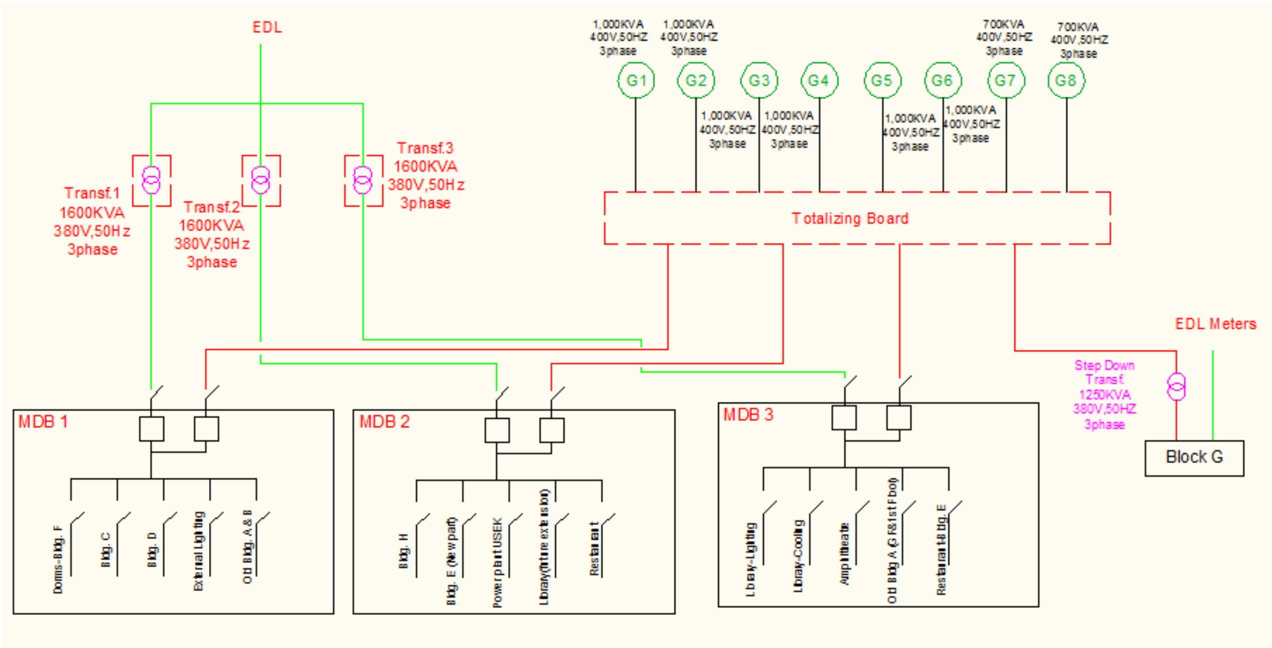
Name	Qty	KVA
Standby Generator 400V/3Ø/50 HZ	6	1,000
Standby Generator 400V/3Ø/50 HZ	2	700
Step Down Transformer MDB 1,2&3	3	1,600
Step Down Transformer Block G	1	1,250

In addition to the above list, USEK has three capacitors out of service since two years. Furthermore, a redundant UPS system is installed for the emergency lights and different emergency loads such as data center and IT equipment.

Figure 3: ATS Panels (Left); Transformers (Middle); Main EDL feeder (Right)

The below single line diagram provides the electrical system distribution from the feeders and generators to the MDBs.

Figure 4: Electrical network single line diagram



2.4. Automation and Metering

USEK has two BMS (Building Management System) installed in Blocks H and F (the dorms). Both systems are connected to the key MEP loads including lighting, ventilation, water pumping system, domestic hot water, space cooling and space heating.
They provide an extensive monitoring tool along with control capabilities through time scheduling.
Another monitoring system - "CS-NET" - is installed in Block H and the library located in Block A providing a basic status of the cooling units with no metering or automation.

Figure 5: Ventilation fans time schedule in Block F

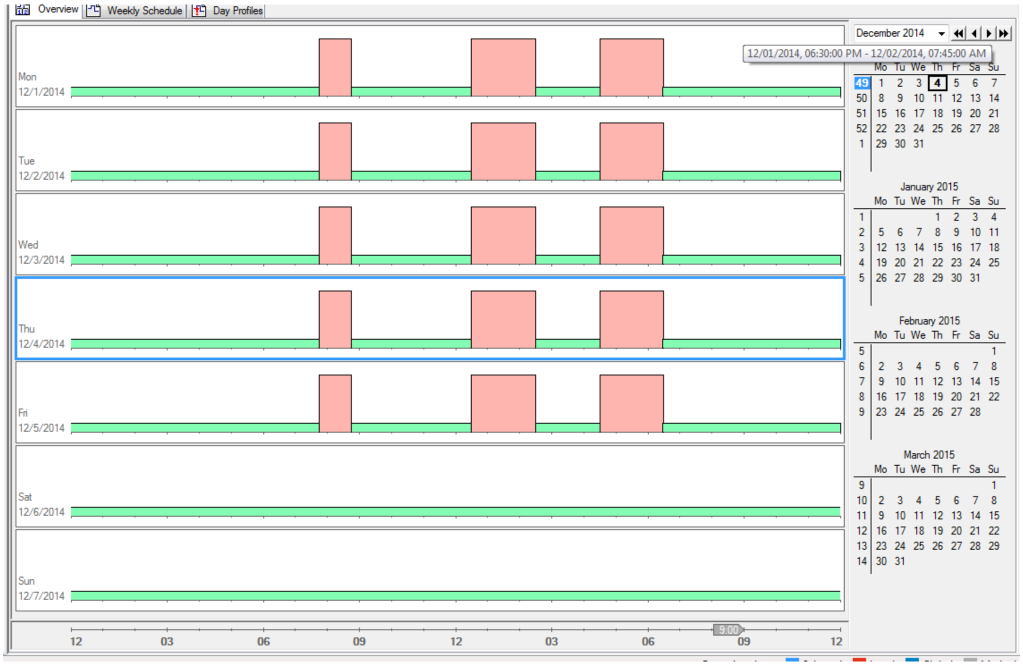


Figure 6: VRF BMS snapshot in Block F

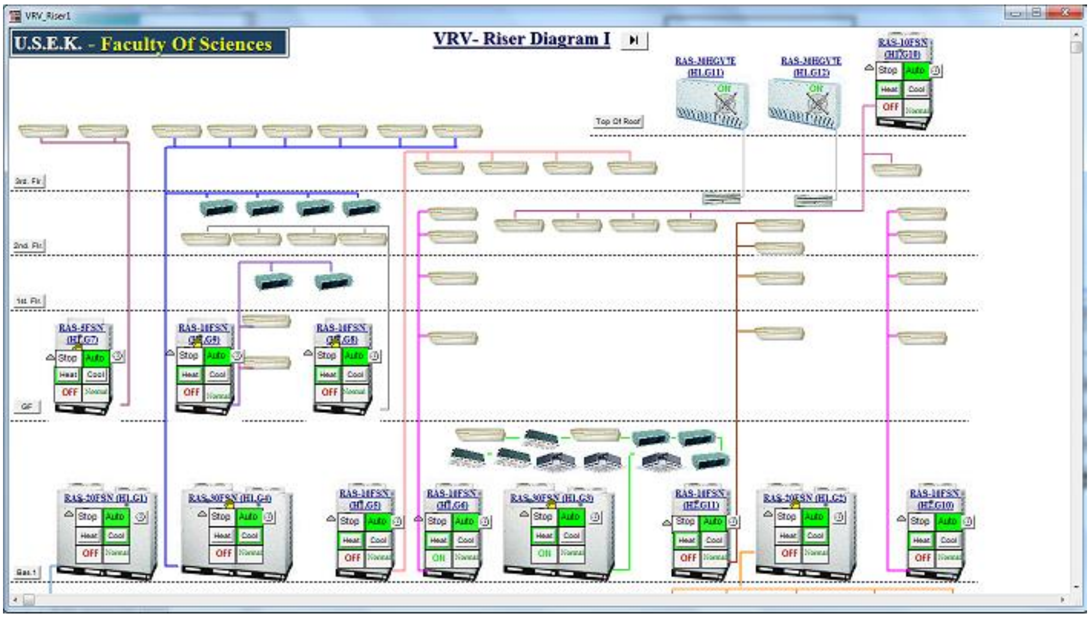
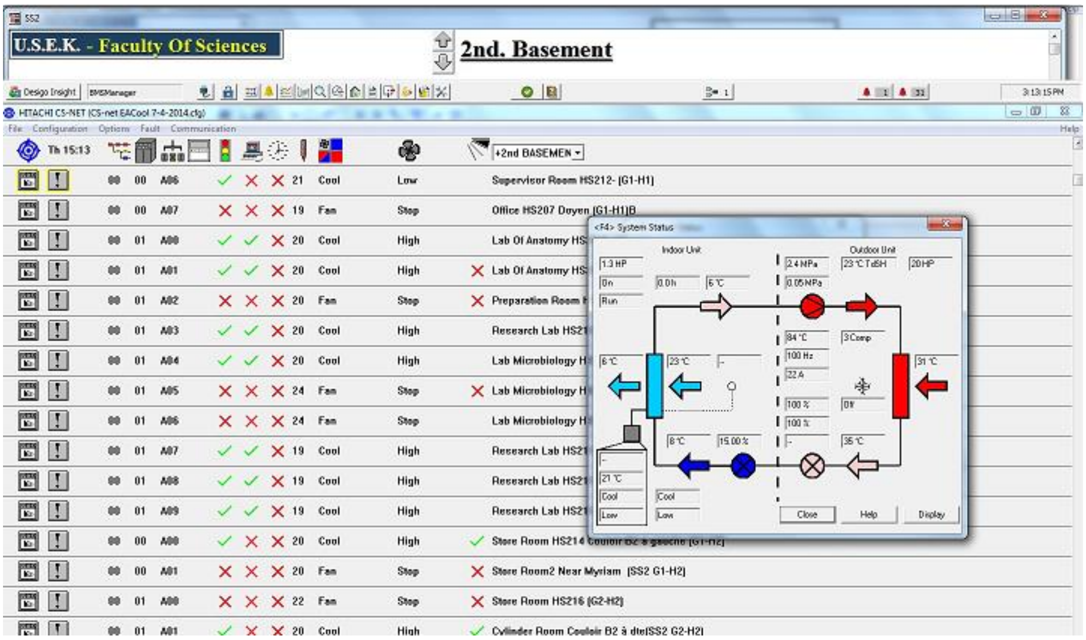


Figure 7: CS-NET snapshot in Block H providing the status of each (indoor/outdoor) cooling unit



2.5. Thermal Energy: Sources and Distribution system

Thermal energy is divided in two categories: cooling and heating.

1. **Cooling Energy:** USEK uses for its cooling purposes a mix of chilled water system, VRF system and split units. There are three McQuay air cooled chillers servicing partially Block H while VRF system covers the remaining parts of this building and the dorms. The rest of the facility is serviced by split/DX units.
2. **Heating Energy:** The demand for heating energy in USEK is characterized by space heating during the winter season covered by the various VRF/Split and DX units . As for the domestic hot water demand, it is provided in the dorms and the restaurant via a solar thermal system . Moreover, two diesel driven hot water boilers are installed in the hot water loop of the dorms to assist the solar thermal system when water temperature drops to below 60°C .

2.6. Annual Energy Consumption

USEK has only one main energy source which is electricity (EDL + Generators). The total energy budget over one year extended from September 2013 till August 2014 is found in the below table.

Table 2: USEK Annual Electrcity Consumption

	Unit	Consumption	Cost
EDL	KWh	3,054,657	$309,332
Generators	KWh	1,258,197	$226,475
Total		**4,312,854**	**$535,807**

*No data was provided for the boilers' diesel consumption.

3. USEK Energy Sources

3.1. Electrical Energy

3.1.2 Introduction

The first step of the electrical energy analysis is to gather all real consumption data and aggregate them in order to find the total electrical energy consumption. As previously mentioned, USEK has two sources for electricity, the EDL electric source and the generators in case of a power failure.
The meter's monthly EDL bills were gathered from January 2013 till December 2013, thus providing a detailed consumption of the facility.

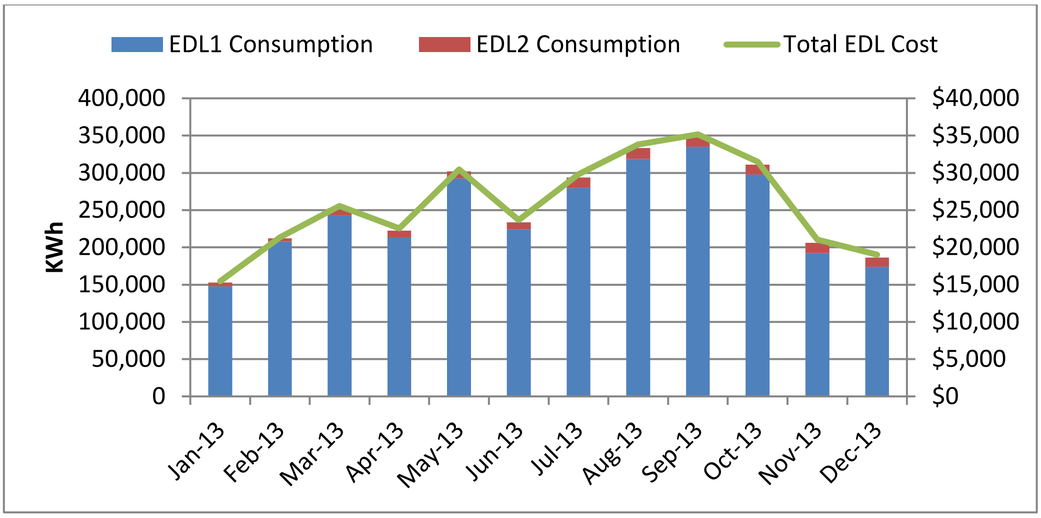
3.1.2 EDL Electrical Energy Analysis and Cost

EDL energy consumption is found in the below table covering the 12 months running from January 2013 till December 2013. It has to be noted that the EDL feeds the USEK through two main transformers: EDL1 based on the industrial tariff and the EDL2 based on the residential tariff having a set of residential meters along the facility. The total energy consumption is found to be 3,054,657 KWh with a related cost of $309,332 annually. These twelve months were chosen to be used as an energy baseline for USEK.

Table 3: Monthly EDL consumption and cost for USEK

	EDL1: Industrial Tariff		EDL2: Residential Tariff		Total EDL	
Month	**KWh**	**Cost**	**KWh**	**Cost**	**KWh**	**Cost**
Jan-13	147,528	$14,753	5,355	$696	152,883	$15,449
Feb-13	207,701	$20,770	4,381	$570	212,082	$21,340
Mar-13	243,070	$24,307	9,632	$1,252	252,702	$25,559
Apr-13	212,877	$21,288	9,632	$1,252	222,509	$22,540
May-13	292,618	$29,262	9,191	$1,195	301,809	$30,457
Jun-13	224,040	$22,404	9,545	$1,241	233,585	$23,645
Jul-13	279,814	$27,981	14,205	$1,847	294,019	$29,828
Aug-13	318,744	$31,874	14,782	$1,922	333,526	$33,796
Sep-13	335,236	$33,524	12,641	$1,643	347,877	$35,167
Oct-13	297,801	$29,780	13,150	$1,710	310,951	$31,490
Nov-13	192,377	$19,238	13,845	$1,800	206,222	$21,038
Dec-13	173,978	$17,398	12,514	$1,627	186,492	$19,025
Annual	**2,925,784**	**$292,578**	**128,873**	**$16,753**	**3,054,657**	**$309,332**

Figure 8: EDL energy consumption and cost-USEK



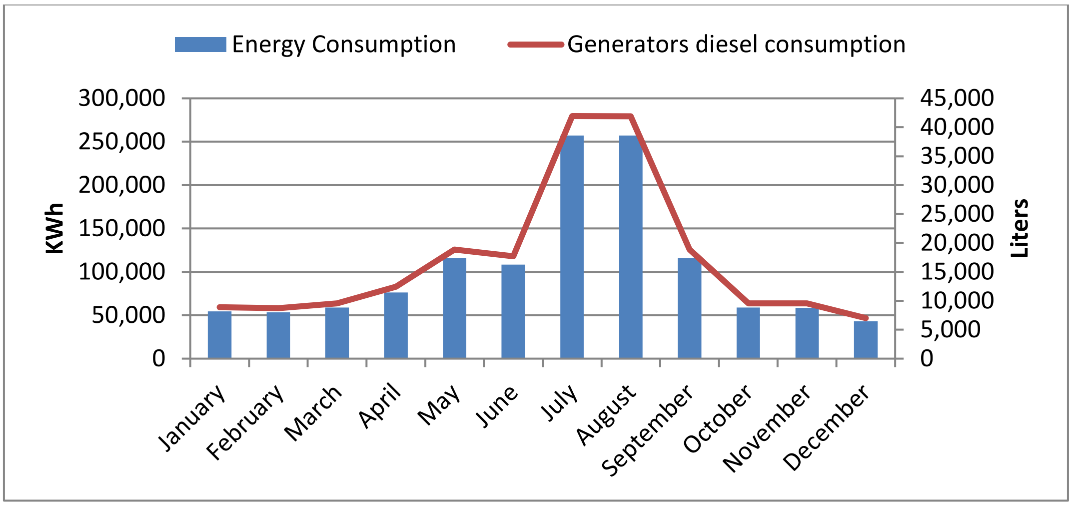
3.1.3 Generators' Electrical Analysis

USEK has six generators having each 1,000KVA capacity and two generators with a 700 KVA rating each. They work during the EDL cut-off period only.
Considering the monthly diesel bills given for USEK, the energy consumption was calculated based on a rate of 0.163Liters/KWh. Results are found in the below table.

Table 4: Generators' Electrical energy consumption and cost over one year

Month	Liters	KWh	Cost	Total $/KWh
Jan-12	8,907	54,642	$9,836	$0.18
Feb-12	8,713	53,455	$9,622	$0.18
Mar-12	9,584	58,797	$10,583	$0.18
Apr-12	12,433	76,274	$13,729	$0.18
May-12	18,880	115,830	$20,849	$0.18
Jun-12	17,677	108,451	$19,521	$0.18
Jul-12	41,928	257,224	$46,300	$0.18
Aug-12	41,923	257,198	$46,296	$0.18
Sep-12	18,874	115,794	$20,843	$0.18
Oct-12	9,583	58,789	$10,582	$0.18
Nov-12	9,573	58,732	$10,572	$0.18
Dec-12	7,011	43,011	$7,742	$0.18
Annual	**205,086**	**1,258,197**	**$226,475**	**$0.18**

Figure 9: Generators' monthly electrical energy consumption and diesel consumption



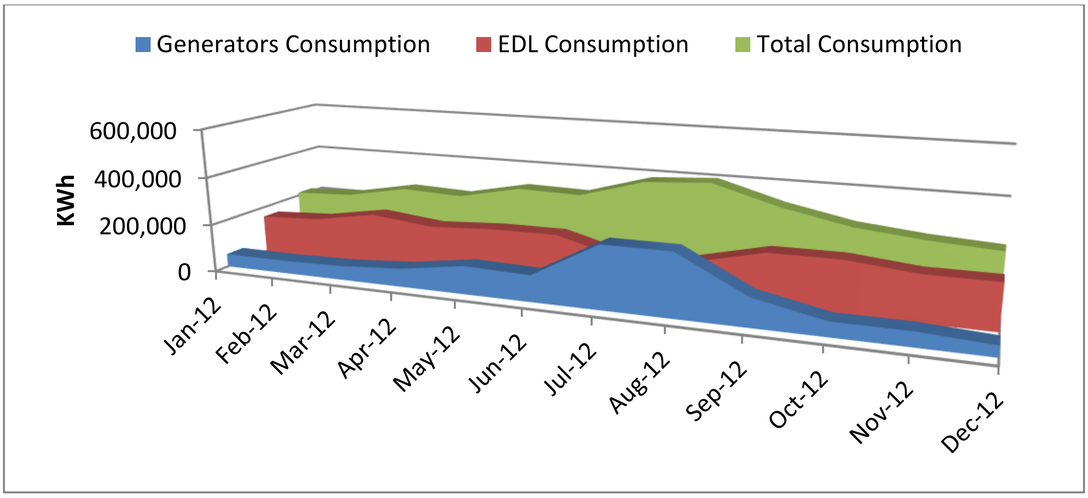
3.1.4 Electrical Energy Baseline

Combining the total energy consumption (KWh) drawn from both the EDL feeders and the generators would lead to the electrical energy baseline of USEK which is found in the below table. The total annual electricity cost is seen to be the $535,807.

Table 5: Monthly Electrical Energy consumption and cost over one year for USEK

	Total EDL		Generators		Total		
Month	**KWh**	**Cost**	**KWh**	**Cost**	**KWh**	**Cost**	**Total $/KWh**
Jan-13	152,883	$15,449	54,642	$9,836	207,525	$25,285	0.122
Feb-13	212,082	$21,340	53,455	$9,622	265,537	$30,961	0.117
Mar-13	252,702	$25,559	58,797	$10,583	311,499	$36,143	0.116
Apr-13	222,509	$22,540	76,274	$13,729	298,783	$36,269	0.121
May-13	301,809	$30,457	115,830	$20,849	417,639	$51,306	0.123
Jun-13	233,585	$23,645	108,451	$19,521	342,036	$43,166	0.126
Jul-13	294,019	$29,828	257,224	$46,300	551,243	$76,128	0.138
Aug-13	333,526	$33,796	257,198	$46,296	590,724	$80,092	0.136
Sep-13	347,877	$35,167	115,794	$20,843	463,671	$56,010	0.121
Oct-13	310,951	$31,490	58,789	$10,582	369,740	$42,072	0.114
Nov-13	206,222	$21,038	58,732	$10,572	264,954	$31,609	0.119
Dec-13	186,492	$19,025	43,011	$7,742	229,503	$26,767	0.117
Annual	**3,054,657**	**$309,332**	**1,258,197**	**$226,475**	**4,312,854**	**$535,807**	**0.122**

Figure 10: Monthly Total Electrical Energy Profil for USEK

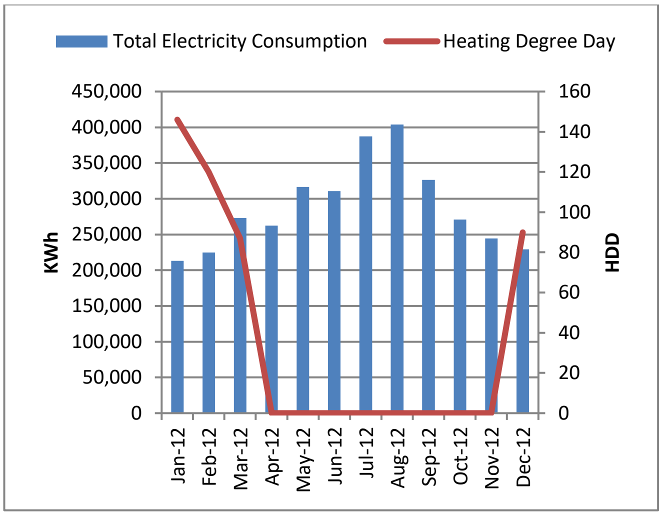


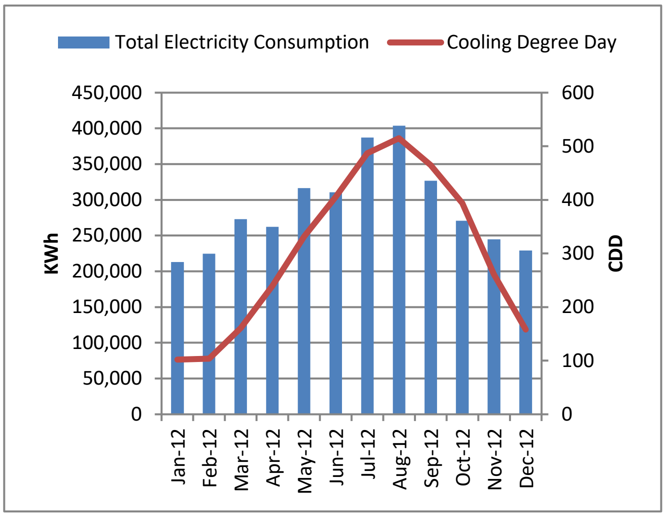
3.1.5 Correlation between Electrical Energy and Weather

An important step in the energy analysis is to understand the relationships between the various parameters affecting the energy consumption and the total energy used. Accordingly, the main parameter weighing on a facility's energy consumption is the climatic conditions (in this case cooling and heating Degree Day). You will find here below two charts showing the relation of the electricity consumption to the cooling and heating demands.

They clearly show that the Cooling Degree Days have a direct – and large impact on the energy consumption due to the high cooling load.

Figure 11: Monthly Electricity Consumption and Degree Days





3.2. Thermal Energy

Thermal energy in USEK includes the hot water and space heating demands.

For space heating, the facility relies on the installed DX/split units and the VRF units without the use of any diesel/gas driven boilers.

As for the hot water demand, it is only found in the dorms building and the restaurant. In both cases solar thermal systems are installed on the roof of each building to supply hot water throughout the year.

In the dorms there are two diesel driven boilers installed in the basement each with 250,000Kcal/hr capacity and supposed to be used for space heating as per the mechanical design. At the present time, space heating is afforded by the VRF system and hot water demand is provided by the solar thermal system installed. The boilers are linked to the solar system and they are used to raise the water temperature to 60°C if needed.

Figure 12: De Dietrich diesel boilers (Left); Solar Panels for the restaurant (Right)

4. USEK Electrical Load Analysis

4.1. Introduction

One key milestone in an energy audit is to perform the comprehensive load inventory for all electrical end uses, then carefully workout the entire operational schedule and load factors of each load in order to have a micro and macro energy consumption analysis and to find the energy balance.

Information and Database process

All the load inventory data (lighting, cooling, motors…) of the facility was entered in an Energy Analysis Software; every item is entered with full details of actual electrical specification (KW) and detailed operational schedule (hours per day, week, month…) in order to perform a total simulation and energy modeling of the facility. This includes a full one year simulation on the energy usage per category.
In the present report the entire electrical and mechanical loads were divided in the following categories:

- **Lighting:** All internal and external lighting systems.
- **Cooling:** A/C split units, VRF and chilled water plant including chillers and related pumps.
- **HVAC Fans:** All heating, cooling and ventilation fans.
- **Motors/Pumps:** Lifts, service pumps…
- **IT Equipment:** IT equipment: servers, computers, routers…
- **Miscellaneous:** All other equipment like kitchen equipment and resistive loads.

4.2. Load Inventory

The entire electrical inventory was divided in two categories; Lighting and equipment.
All the existing equipment in the facility as well as all lighting fixtures are listed in tables found in *Appendix A,* a sample of the two tables is shown below.
Annual KWh of every equipment or load has been listed according to the detailed operational schedules used and the full reconciliation of the USEK's total electrical energy consumption as found in the energy baseline.

Table 6: Lighting Inventory-Sample

Type	Location	No. of Fixtures	Lamp Wattage (W)	Ballast Wattage (W)	Installed Wattage (W)	Total Installed Wattage (KW)	Annual Energy Use (KWh)
Block A							
Panel 36W	GF-orientation office	24	36	0	36	0.864	1,820
Hal 70W	GF-orientation office	33	70	0	70	2.31	4,865
Fluo T8 4x18W	GF-B.A.E.S	23	72	12	84	1.932	4,069
Fluo T8 2x36W	GF-B.A.E.S	6	72	12	84	0.504	1,062
Hal 70W	GF-registration	52	70	0	70	3.64	7,667
Fluo T8 2x58W	GF-registration	17	116	16	132	2.244	4,726
PL 2x26W	GF-registration	3	52	0	52	0.156	329
Economy 2x23W	GF-offices& common areas	50	46	0	46	2.3	4,844

Table 7: Equipment Inventory-Sample

Name	Location	No. of Units	Input Capacity (KW)	Total Capacity (KW)	Annual Energy Use (KWh)
Elevator	Block A-Music	1	11	11	28,398
Elevator	Block A-Library	1	11	11	28,398
Elevator	Block A-Library	1	7.5	7.5	17,443
Hot water pump	Block A-Boiler	1	0.5	0.5	1,084
Pressure pumps	Block A	2	1.3	2.6	2,368

4.3. Lighting System Description

Lighting system in USEK consists of a large number of fixture and bulb types. This is mainly due to the various phases of constructions of the campus. Accordingly, a heteroclite usage of Halogen type fixtures, CFL ones, Linear T8 fluorescent and HID for external lights is noticed. Lately, the facility management initiated the usage of LED in block H. The campus has been also looking for a campus wide Led retrofit which has been developed in one of the Energy Efficiency Measures in the present report. here after is a set of picture depicting the variety of lighting systems in the campus.

Figure 13: 2D 36W in block E (Left); PL 58W in offices (Middle); Linear fluorescent T8 in the Library (Right)

Figure 14: LED lighting fixtures in basement 3-Block H

Figure 15: External Lighting fixtures

The below table provides the lighting BOQ of USEK. The total lighting load installed is found to be **532KW**. Taking into consideration the schedule of work in the various areas, the lighting system was found to have an annual energy consumption of **1,246,756KWh**.

Table 8: USEK-Lighting BOQ

USEK Lighting BOQ			
Type	**Number**	**Total KW**	**Annual Energy Use (KWh)**
Linear Fluorescent Type			
Fluo T8 18W	141	3.384	4,841
Fluo T8 36W	338	14.196	24,743
Fluo T8 2x18W	9	0.378	1,228
Fluo T8 3x18W	12	0.768	83
Fluo T8 4x18W	683	57.372	140,855
Fluo T8 2x36W	378	31.752	96,452
Fluo T8 4x36W	108	17.28	49,098
Fluo T8 2x58W	296	39.072	79,100
Fluo T5 28W	1,981	55.468	156,326
Halogen			
Hal 50W	216	10.8	5,116
Hal 70W	1,135	79.45	107,280
Hal 150W	2	0.3	66
Hal 2x300W	78	46.8	174,396
Compact Fluorescent			
PL 26W	416	10.816	16,492
PL 2x26W	1,192	61.984	136,875
Panel 36W	120	4.32	10,264
PL 58W	654	36.943	48,557
E27 23W	119	2.737	2,578
2D 36W	78	2.808	8,074
Economy 2x23W	200	9.2	21,217
Economy 30W	3	0.09	283
Economy 36W	29	1.044	2,689
Economy 2x36W	108	7.776	39,427
Metal Halide			
MH 400W	42	16.8	63,809
Pressure Sodium			
PS 250W	40	10	39,000
Incandescent			
Inc 100W	34	3.4	6,766
LED			
Projector LED 100W	10	1	628
LED T8 16W	299	4.784	6,061
LED 20W	12	0.24	68
LED 100W	8	0.8	1,571
Other			
F4-T8 2x36W +2xspot 50W	4	0.736	1,737
Spot 12W	38	0.456	1,076
Total		**531.76**	**1,246,756**

4.4. Cooling System Description

Cooling system presents the most critical energy end use in USEK since it combines the classical cooling system by using the DX/split units and the new technologies with the VRF and the air cooled chillers. Their distribution and location can be found as listed below:

- VRF (Variable Refrigerant Volume): Servicing the dorms (building F), the new constructed zone of building H, the church and the library in building A.
- Air Cooled Chillers: Servicing class rooms and offices of building H that are not cooled with the VRF, in addition to the new constructed conference rooms in basement 3 of the same building.
- DX/Split units: Provides cooling through all the facility excluding the zones listed above.

4.4.1. DX/Split Units

Split units or direct expansion units (DX) are the traditional air conditioning concept. This system dominates in USEK and various sizes were inventoried through the facility aging between 3 years to more than 10 years in some areas.

Figure 16: Outdoor units (Left); Indoor units (Right)

Table 9: Split units Inventory-Sample

Name	Location	No. of Units	Input Capacity (KW)	Total Capacity (KW)	Annual Energy Use (KWh)
AC 3Tons	Music	8	3.9	31.2	47,673
AC 18000Btu	Music	8	1.9	15.2	23,972
AC 24000Btu	Music	38	2.6	98.8	151,742
AC 12000Btu	Music	62	1.3	80.6	123,790
AC 28000Btu	Music	14	3	42	62,681

If we go deep in the cooling capacities installed with their related energy consumption, the DX/split units are seen to have 68% of the total cooling energy consumption with around 1,740,778KWh per year.

4.4.2. Air Cooled Chillers

USEK has three similar McQuay air cooled chillers model "McSmart 500CR" located on the roof of block H. Chilled water circulation is provided through 4 primary pumps. The system operation is based on two main networks that are described in the below table.

Table 10: Chilled water networks description

	Serviced Area	Number of Chillers	Number of primary pumps	Periods of Operation
Network 1	New constructed classes and offices in block H	1	2	May till September
Network 2	six conference rooms with their lobby in basement 3-block H	2	2	Occasionally

Concerning the chillers, a technical data sheet is displayed here after.

Figure 17: Technical data sheet for the chillers of USEK

Technical data

Heat pump

McSmart		160CR	190CR	210CR	240CR	320CR	400CR	500CR
Cooling capacity (1)	kW	47,1	52,9	63,6	75,6	96,0	112,6	144,7
Power input (1)	kW	18,3	20,1	23,4	27,1	35,5	41,0	50,7
Heating capacity (2)	kW	55,1	57,1	67,2	81,8	110,3	118,1	157,5
Power input (2)	kW	19,5	20,7	25,6	28,5	38,1	45,4	57,3
COP (1)		2,57	2,63	2,72	2,79	2,70	2,75	2,85
Compressor					Scroll			
Quantity		2	2	2	2	4	4	4
Total oil charge	l	6,5	6,5	8,0	13,0	13,0	13,0	26,4
Reduction steps number		2	2	2	2	4	4	4
Refrigerant					R407C			
Circuits number		2	2	1	1	2	2	2
Charge	kg	13,0	15,0	26,0	26,0	38,0	42,0	56,0

Figure 18: Chillers on the roof of Block H (Left); Primary chilled water pumps (Right)

It is to be noted that the chilled water system has an "operation panel" providing many features and settings according to various parameters such as time schedule, cooling/heating temperature settings, the status of each compressor…. Besides, many alarms can be set by the operator to meet the desired sequencing and control. However, this automation system is in a passive status for the time and is solely used for manual control and for checking any alarm 3 times per day.

Figure 19: Operation panel (Left); Chilled water temperature settings (Middle); Operation Mode (Right)

You will find below the list of the chilled water plant components installed with the rated annual energy use. The chilled water pumps are of the primary only type and do not have any VFD.

Table 11: List of Chillers along their chilled water pumps

Name	Description	No. of Units	Input Capacity (KW)	Total Capacity (KW)	Annual Energy Use (KWh)
Chiller1	Classes	1	50.7	50.7	44,434
Chillers2-3	Conference rooms in B3	2	50.7	101.4	79,091
Chilled water pumps	Network 1	2	5.5	11	2,450
Chilled water pumps	Network 2	2	2.2	4.4	2,130
Total				**167.5**	**128,104**

4.4.3. VRF System

On the top of the chilled water system and split/DX cooling units, USEK has been investing in VRF in its two buildings H and F. They provide both space cooling during summer and space heating during winter.

Figure 20: VRF Outdoor units for the Library with dehumidifier inside (Left); VRF O.U. for the Students Library (Middle); Thermostats for the church (Right)

Hereafter is a sample of the inventoried VRF indoor/outdoor units. The total installed capacity is 483KW with a related annual energy consumption of 695,592KWh.

Table 12: VRF units Inventory-Sample

Name	Description	No. of Units	Input Capacity (KW)	Total Capacity (KW)	Annual Energy Use (KWh)
O.U.1	VRF-Faculty of Sciences	3	1.4	4.2	3,075
O.U.2	VRF-Faculty of Sciences	2	3.2	6.4	4,587
O.U.3	VRF-Faculty of Sciences	4	3.2	12.8	9,059
O.U.4	VRF-Faculty of Sciences	9	7	63	45,152
O.U.5	VRF-Faculty of Sciences	3	15.3	45.9	32,789

The installed BMS in block F (Faculty of Sciences) enables a specified schedule to be fixed for the VRF in terms of operational hours and mode of operation (cooling/heating). This situation is almost the same for the dorms-block F- with an individual control for the indoor units in each room.

In addition, there are seven VRF outdoor units that cover the church's cooling where a fixed schedule is maintained all over the year.

Other areas in USEK depend also on VRF system such as the main library, Phoenix center, E zone and the related archive where specific conditions must be maintained. For that reason, three outdoor units each with 10tons cooling capacity and two other units each with 5tons cooling capacity are installed, providing good conditions for books storage.

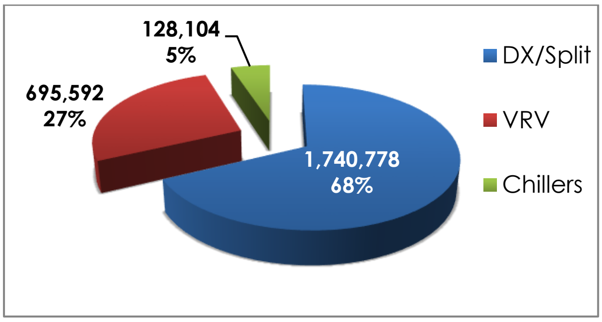
Figure 21: THermostats for VRF control in students library (Left); CS-NET readings linked to the archive VRF units (Middle); Ambiant conditions for the books storage room (Left)

A basic CS-NET program is installed for the indoor and outdoor units servicing the two basements of the library archive. It is used for monitoring only without any automation or control .

4.4.4. Cooling Energy Breakdown

Combining the various cooling systems' capacities and annual energy consumption will lead to an accurate breakdown per type of units and is found here below, showing that the DX and split units have the largest share.

Figure 22: Cooling Energy Breakdown (KWh)-USEK



4.5. HVAC Fans

HVAC fans are the center systems for a good Indoor Air Quality as they ensure the proper temperature; humidity and fresh air are attained while extracting smokes and odors. The facility has a large number of HVAC fans that fall under the below categories:

- **Fan Coil Units (FCU):** serving areas supplied by the chillers.
- **VRF indoor units:** serving areas supplied by the VRF and found in the server room.
- **Exhaust Fans:** they are mostly used to extract air from kitchens, parking and laboratories. Extractor fans in basements operate on CO sensors.
- **Fresh Fans:** they are mostly used to produce fresh air inside the parking.

Figure 23: Exhaust Fans in Block E (Left); Exhaust Fans in Block F (Right)

The below table provides a sample of the HVAC fans inventory installed in the facility along the related annual energy consumption as compiled in the energy analysis software and re-conciliated with the energy baseline. The total annual energy consumption was found to be **34,917KWh** with an installed power of **55KW**.

Table 13: HVAC fans Inventory-Sample

Name	Location	No. of Units	Input Capacity (KW)	Total Capacity (KW)	Annual Energy Use (KWh)
EF-B5	Block H-SS1 -4000cfm-	1	1.6	1.6	1,291
EF-B5	Block H-SS1-3000cfm-	2	1.2	2.4	1,940
FAF-B5-	Block H-SS2-4000cfm-	2	1.6	3.1	2,581
EF-B4	Block H-SS1 -4000cfm-	1	1.6	1.6	1,291
EF-B4-	Block H-SS1-3000cfm-	2	1.2	2.4	1,940

FAF-B4-	Block H-SS2-4000cfm-	2	1.6	3.1	2,581

4.6. Pumps and Motors

In addition to the chilled water pumps, USEK has a series of pumps for various end uses such as domestic water pumps, hot water circulators, fire fighting pumps...They are all operational on a time or demand based ways. In addition, USEK has a number of motors for various end uses such as elevators.

The below table provides a sample on the motors inventory. The total annual energy consumption is found to be **260,392KWh** with an installed power of about **173KW**.

Table 14: Motors sample inventory-USEK

Name	Location	No. of Units	Input Capacity (KW)	Total Capacity (KW)	Annual Energy Use (KWh)
Elevator	Block A-Music	1	11	11	22,802
Elevator	Block A-Library	1	11	11	22,802
Elevator	Block A-Library	1	7.5	7.5	14,006
Hot water pump	Block A-boiler	1	0.5	0.5	870
Pressure pump	Block A-water treatment	2	1.3	2.6	1,901
Circulating pump	Block A-water treatment	2	0.3	0.6	156

Figure 24: Lifting pumps (Left); Hot water circulating pumps (Middle); Potable water pumps (Right)

4.7. IT Equipment

The total IT assets that include the data centre, laptops, desktops, routers and all other IT auxiliary equipment have been estimated. Two main UPS are implemented for the servers with 34KVA capacity each. For the remaining IT loads, several UPS are spread throughout the facility, with different capacities ranging from 30KVA to 60KVA. The installed power and annual energy consumption are found in the below table.

Table 15: IT equipment inventory-USEK

Name	Location	No. of Units	Input Capacity (KW)	Total Capacity (KW)	Annual Energy Use (KWh)
PCs	Administration	300	0.06	18	28,665
PCs	Laboratories	440	0.06	26.4	5,787
Server	USEK	1	10	10	30,301
Total				**54.4**	**64,753**

Figure 25: UPS for servers (Left); Server room (Right)

4.8. Miscellaneous Loads

Equipment that do not fall in the above categories, are classified as miscellaneous loads. The Miscellaneous loads inventory along with their individual annual energy consumption is shown below.

Table 16: Miscellaneous loads inventoy-USEK

Name	Location	No. of Units	Input Capacity (KW)	Total Capacity (KW)	Annual Energy Use (KWh)
Freezer	Block C	1	7	7	15,942
Washer	Block F-SS1	4	4	16	20,166
Dryer	Block F-SS1	2	4.5	9	11,344
Iron	Block F-SS1	3	1.5	4.5	2,158
Freezer	Block H-Lab	1	7	7	15,942
Buggies	USEK	7	5	35	47,950
Lab equipment	Block H	1	10	10	7,056
kitchen equip	Cafeteria	1	10	10	19,180
TV	Dorms	50	0.2	10	1,825
Total				**108.5**	**141,562**

Figure 26: Washers and dryers (Left); Buggies (Right)

4.9. Electrical Energy Balance (Load and Cost/Consumption Breakdown)

Compiling all the data from the load inventory and the energy analysis would yield to USEK's energy balance which provides the breakdown of the power installed, energy consumed and energy costs.

- **Electrical Load Breakdown:** Giving the total installed electrical power (KW) along with the percentage share of each category. The total installed load in USEK exceeds the 2,903KW.

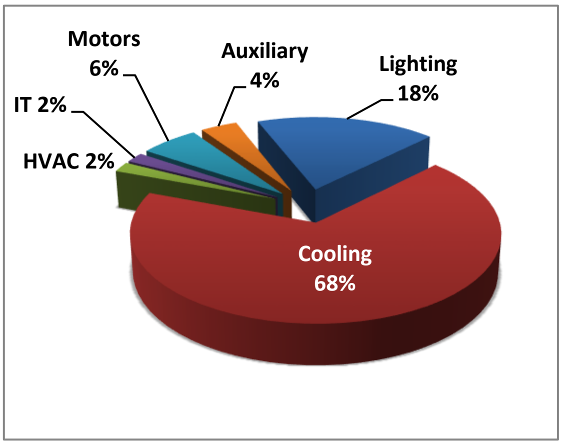
- **Energy Consumption and Cost Breakdown**: Giving the total energy consumption (KWh) and cost along the percentages for each category. Electric bills are not itemized and give no indication how much one spends each month to light his facility, operate motors etc. The macro and micro analysis as done in the energy analysis software enables a comprehensive breakdown per individual end use or per category.

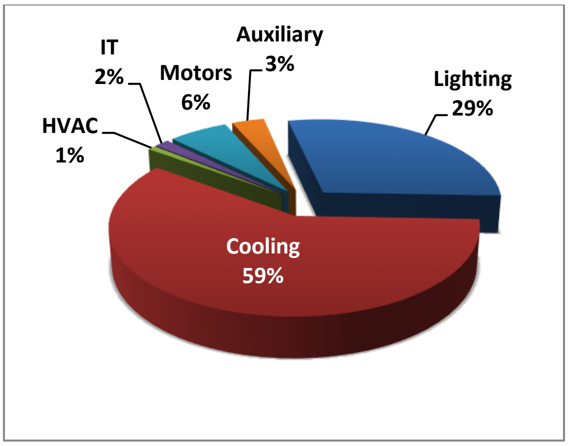
The below table provides the load and cost breakdown in USEK while the following figure depicts the pie chart for both parameters.

Table 17: Electrical load breakdown (Left); Energy Cost Breakdown (Right)

Category	KW	Percentage		KWh	Cost	Percentage
Lighting	532	18%		1,246,756	$122,444	29%
Cooling	1,979	68%		2,564,474	$335,348	59%
HVAC	55	2%		34,917	$6,365	1%
IT	54	2%		64,753	$10,161	2%
Motors	173	6%		260,392	$40,670	6%
Miscellaneous	109	4%		141,562	$20,820	3%
Total	**2,903**	**100%**		**4,312,854**	**$535,807**	**100%**

Figure 27: Facility Load Breakdown (Left); Facility Energy Breakdown (Right)



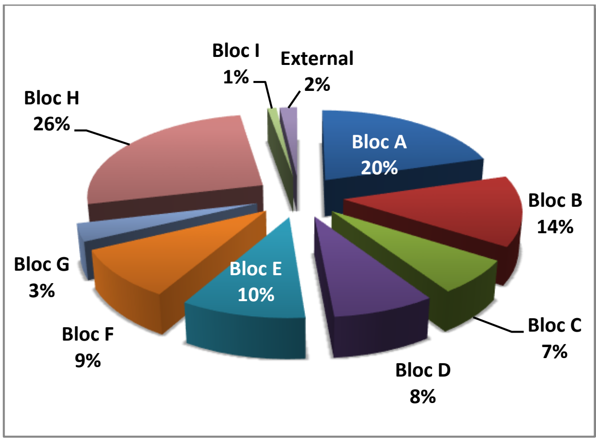


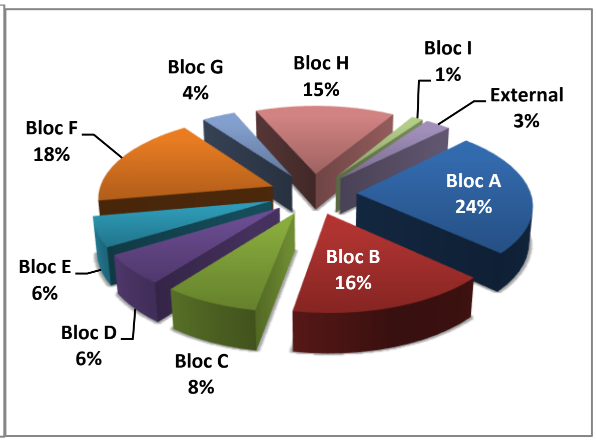
It is seen that the cooling loads are the largest energy consumers with about 59% of the total while they represent 68% of the installed power. Lighting loads come second with a total of 29% of the total energy consumption followed by motors loads.

Energy Breakdown per Building

One important energy breakdown is the one related to the various buildings /Blocks in USEK. below are the two pie charts whereby clearly Block A has the largest energy consumption and loads followed by Blocks B and F (dorms) .

Figure 28: Load breakdown per Block (Left) ; Energy Consumed per Block (Right)





4.10. Indoor Air Quality-USEK Present Situation

Indoor air quality (IAQ) focuses on airborne contaminants including thermal comfort quality and air quality, covering therefore temperature, humidity, CO_2, CO and VOC (Volatile Organic Compounds) levels.

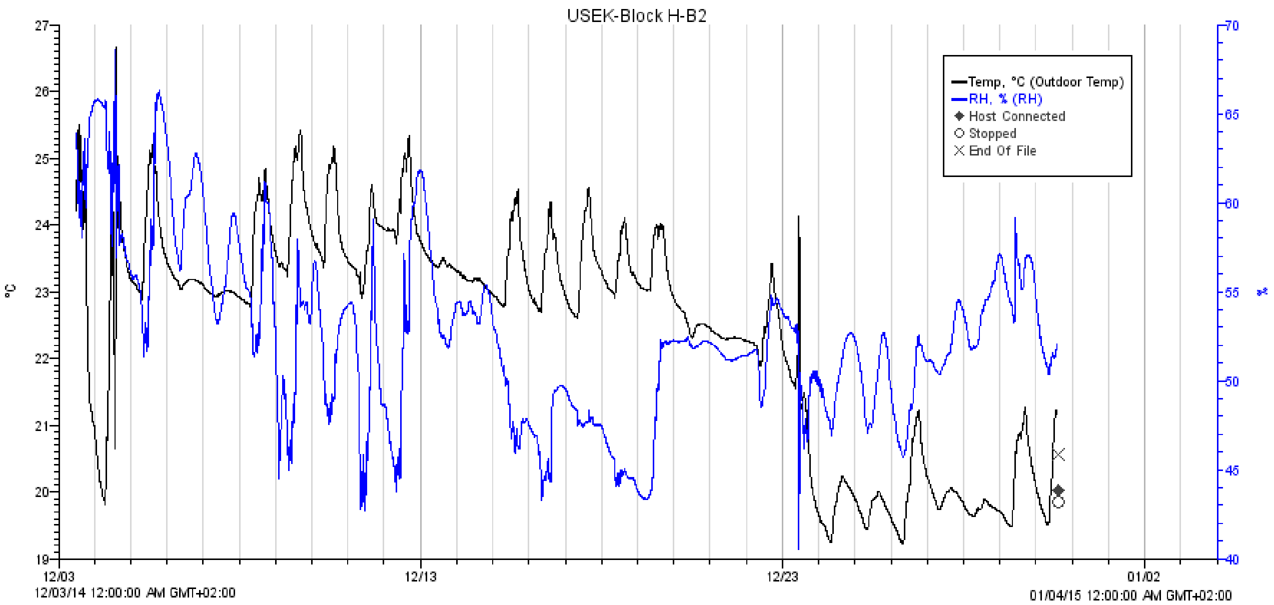
When it comes to standards, the main guidelines refer to standards promulgated by the American Society of Heating, Refrigerating and Air-conditioning Engineers Inc. (ASHRAE). These are found in the ASHRAE documents *Ventilation for Acceptable Indoor Air Quality* (ASHRAE 62-2001) and *Thermal Environmental Conditions for Human Occupancy* (ASHRAE 55-2004).

Humidity and Temperature

There is no "ideal" humidity level and temperature suitable for all building occupants. Many factors, such as personal activity and clothing may affect personal comfort. Acceptable relative humidity levels should range from 20 percent – 65 percent year-round. Levels less than 20 percent in the winter and greater than 65 percent in the summer should be considered off the standards. Elevated relative humidity can promote the growth of mold, bacteria, and dust mites, which can aggravate allergies and asthma. To achieve maximum occupant comfort, relative humidity should be maintained between 30 % – 65 % .

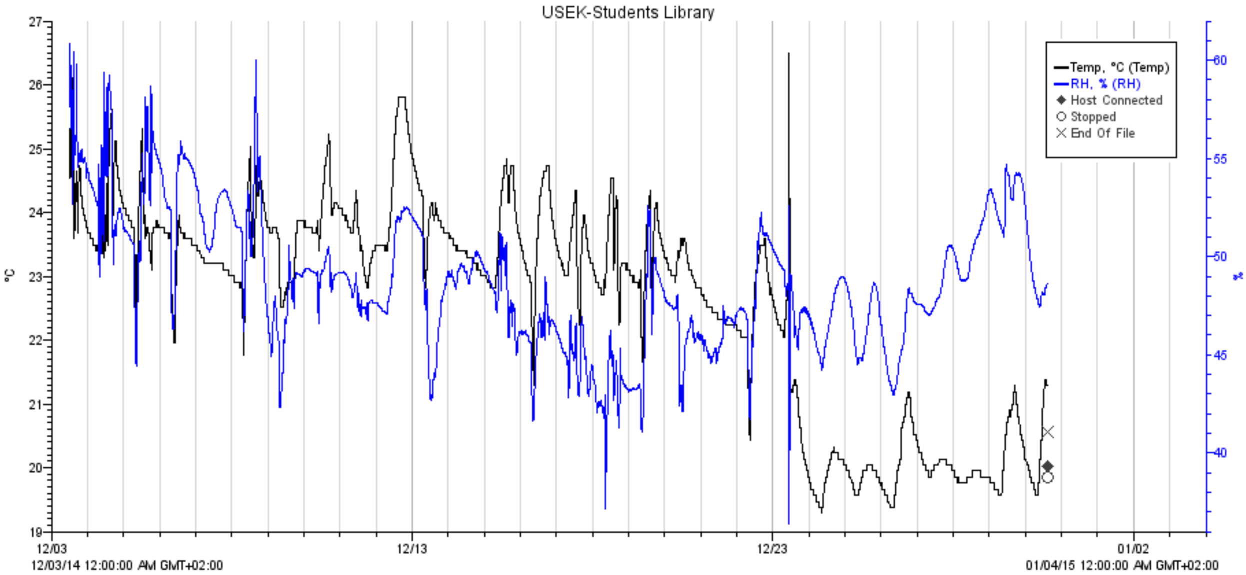
In order to showcase the situation, we have installed data loggers in various areas of the facility and the results are shown here after.
two sets of graphs are shown, each with clear indication on the targeted location. The graphs include the plotting of both the temperature and relative humidity on the basis of a logging done every 5 minutes.

a)



The graph above shows the conditions measured in building H basement 2 where laboratories and some offices are located. We can note that temperature revolves around 24 degrees while humidity varies from 45% to 65%. During holidays temperature drops to 20degrees and humidity reaches 55%.

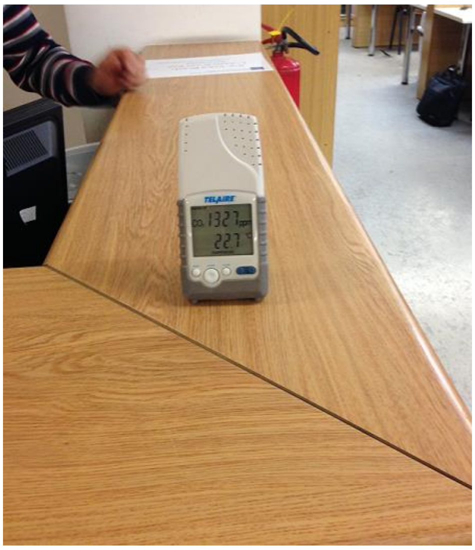
b)



The second graph depicts the temperature and relative humidity in the student library where high temperatures and humidity are recorded. A peak of 26 degrees in September is measured in the library with a relative humidity exceeding 60%. An improvement for the ventilation system operation must be done in order to ensure better comfort conditions for students.

It has to be noted that a CO_2 measurement was undertaken in some of the enclosed areas of USEK and results were at the limit in the cafeteria with an average of 1,000ppm and in the basements of block H while in the main library in block AB, this level exceeds 1,320ppm which requires an improvement in the ventilation system and air circulation in order to upgrade the comfort conditions for the students.

Figure 29: CO_2 level and temperature measured in library block AB-Main Library



5. Energy Efficiency Measures

Energy budgets represent one of the highest cost centers in a facility operation. On the other hand, in their aim for greening their operations, buildings today are also investing in energy efficiency as energy is by far the largest contributor to their CO_2 emissions.
Energy efficiency is a continuous development program that includes a comprehensive look and optimization at every aspect of the facility and at all levels of operations, loads and systems.

Taking the present situation of USEK as a baseline, we have investigated a large number of energy efficiency solutions which could yield to substantial cost optimization. Every opportunity is called an Energy Efficiency Measure (EEM). Our basis for this analysis is to develop a robust, fiscally disciplined program targeting energy efficiency and conservation investments across the campus with the emphasis on measures that will have a substantial impact on energy consumption and greenhouse gas emissions while at the same time offering positive economic return.

The various EEMs modules are divided as follows:

1. **EEM1: Low Cost/No Cost Energy Efficiency Measures**
   1.1. Hot water pipes insulation
   1.2. Thermal losses reduction
   1.3. Chilled water temperature reset
   1.4. Re-Commissioning of all electrical systems in USEK
   1.5. Employee Engagement
2. **EEM 2: Lighting Retrofit-LED Retrofit**
3. **EEM 3: Occupancy sensor for lighting and cooling systems**
4. **EEM 4: Retrofit Split Units with DC Inverter technology**
5. **EEM 5: VRF Retrofit for the DX units in USEK ("What IF" Scenario)**
6. **EEM 6: Waste Heat Recovery**
7. **EEM 7: Roof Insulation-Green Roof**
8. **EEM 8: BMS System Upgrade and Extension**

The following sections develop every measure recommended for the facility with the technical background and financial feasibility.

5.1. EEM 1: Low Cost/ No Cost Energy Efficiency Measures

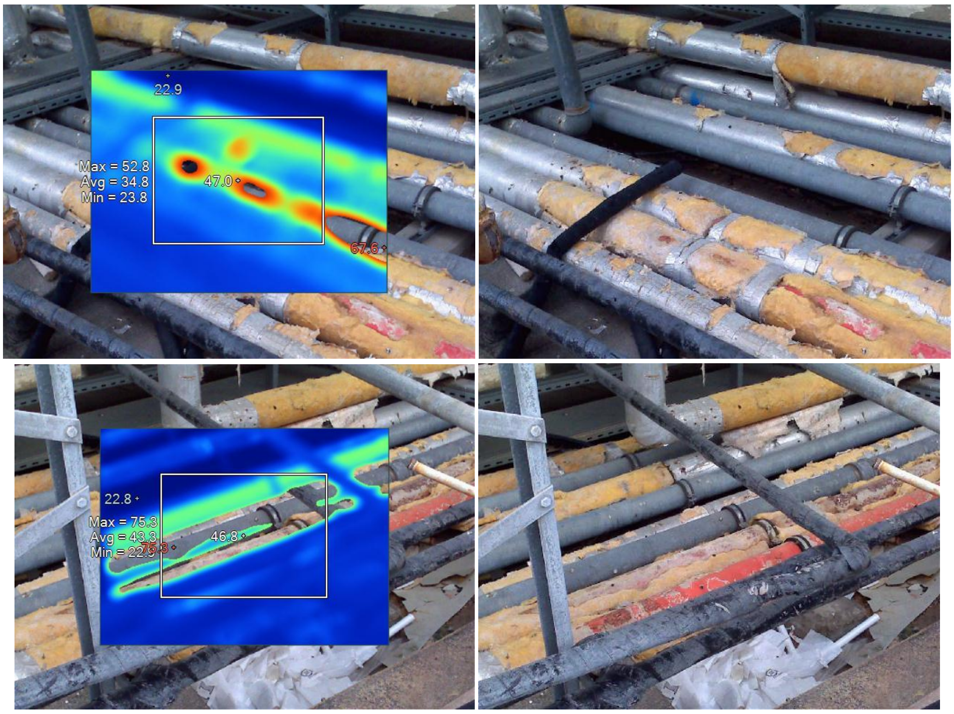
USEK has the opportunity to have important cost savings from virtually very little or no CAPEX at all. Those measures are called "Low Cost / No Cost EEMs".

The flexibility of operation along with a proactive operator approach is of a prime importance in the implementation of those measures. Ultimately, every small action can count in the bottom line and this should be the mindset throughout all departments of USEK.

5.1.1 Hot water pipes insulation

During the field audit, some thermal images were taken throughout the hot water pipes network in order to determine the potential areas of poor thermal insulations. Improving the insulation will have a good impact on the thermal energy consumption in the system

Figure 30: Thermal image on hot water pipes



5.1.2 Thermal losses reduction

When it comes to energy performance, the largest impact of an HVAC system in buildings is the overall building envelope. In fact, large infiltration of outside humid air to cooled spaces along with substantial heat gains from solar radiations provide a big challenge for the cooling demand. As HVAC loads represent by far the largest energy consumer in USEK, the building envelope weaknesses have a direct impact on both the energy consumption/costs through the increase of the running time of cooling compressors and indoor air quality.
Most mitigation measures would require very little CAPEX and can therefore be included in this list of low cost/no cost EEMs. The key measures are:

- Weather stripping on doors
- Air curtains' installation.
- Installation of mechanical door closers.

We recommend a thorough assessment throughout all the parts of the various buildings in parallel with the awareness program in order to validate all potential weaknesses and mitigate them. Targets are all outdoor/indoor accesses and all cooled spaces with potentially opened doors.

Figure 31: Open windows and doors in cooled areas

As the space is cooled during summer period and heated during winter period, the reduction of thermal losses at any single point will have an impact. In many cases weather-stripping should be enough.

Table 18: Thermal losses improvement savings

Measure Description	KWh savings	Cost Saving ($)
Thermal losses improvements	25,645	$3,334

- ➔ It has to be noted that USEK has two boilers in block F each with 250,000Kcal/hr for space heating. Instead, rooms are heated via VRF system and the boilers operation is restricted to act as back up for the solar system. Retrofitting these two boilers with heat pump can record dramatic savings in the diesel consumption.

5.1.3 Chilled water temperature reset

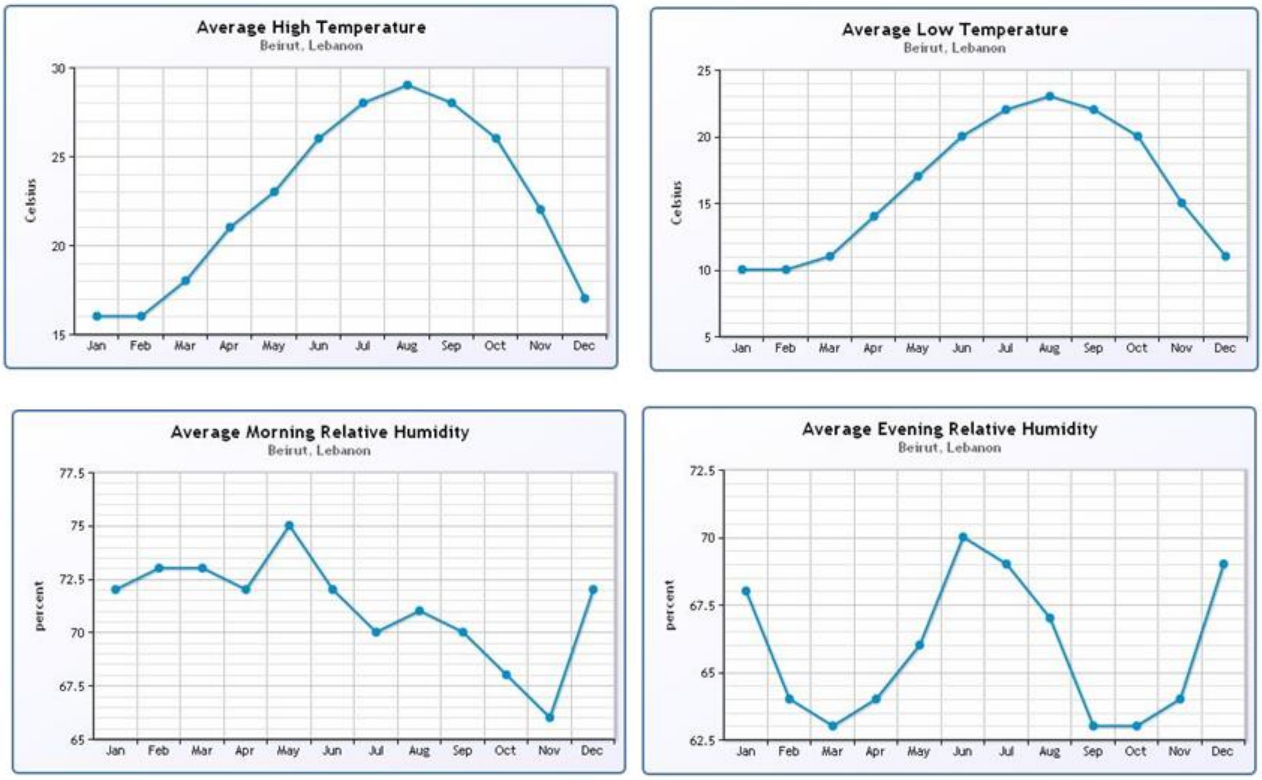
Optimizing the operating temperatures of cooling machines is one of the most important aspects of efficient operation. The COP (Coefficient of Performance) of any machine depends strongly on the temperature difference against which it operates. Cooling plants typically keep this differential higher than it needs to be, providing the user with an opportunity for major energy savings.

Chilled water systems are commonly designed to provide full cooling load with a chilled water temperature of about 7°C chilled water output 35°C ambient temperature. Plant operators typically leave the chilled water temperature fixed at this value or some other. This is inefficient for most applications, such as air conditioning, where the load is well below its maximum most of the time. Typically, you can raise the chilled water temperature by 1°C to 4°C for much of the time. Even at full load, the typical over sizing of airside components (air handling units, fan-coil units, etc.) usually allows some increase in chilled water temperature.

USEK's case:

The weather conditions in Lebanon are well segmented into four different seasons: Spring during which the temperature varies between 14^{0}C and 23^{0}C, summer during which the temperature reaches levels around 29°C, fall where the temperature varies between 15^{0}C and 26^{0}C and finally winter when temperature can go as low as 10°C. Those differences are clearly depicted in the below historical averages.

Figure 32: Beirut-Lebanon Historical Temp/RH averages



USEK is currently operating the chillers only from May to September at a leaving temperature of 6°C throughout all this period without any variation, we would recommend raising this level to 8°C.

➔ The savings that can be attained annually could easily top the 6% of the chillers' energy consumption. An estimated 7,411KWh reduction per year for the three chillers can be achieved which will bring in around $963 of cost savings on KWh.

Table 19: Chilled water temperature reset savings

Measure Description	KWh savings	cost Saving ($)
Chilled Water Temperature Reset	7,411	$963

5.1.4 Retro-commissioning of all HVAC system in USEK

Background

During construction, commissioning is one of the last steps in the process before a facility is turned over to the owner. It establishes and documents that the installed systems and components function and perform in compliance with the project's requirements.

By comparison, retro commissioning of HVAC systems applies the commissioning process to systems within an existing building with the goal of restoring functionality and performance of those systems comparable to when the building was new, with one exception: Facilities change, creating changes in demands on the HVAC systems. In those cases, retrocommissioning identifies the changes needed to meet the new performance demands.

Why is retro commissioning a necessity? In all system operations, sensors and controls drift out of calibration, damper seals wear and fail to seal properly, ducts develop leaks, and dirt accumulates on heat-transfer surfaces. All of these issues contribute to performance creep. But retro commissioning does more than counteract performance creep.

Most buildings operating today never went through a commissioning process when they were new. Inefficiencies built into those systems were never identified or corrected. Even with the best maintenance practices, these inefficiencies will continue to be a drag on system efficiency and performance.

Retro commissioning helps facility managers identify the entire range of issues harming system performance, including system creep, improper operation, and design errors and defects that date back to the original installation. Typical deficiencies identified during the process include sensors and controls out of calibration, leaking dampers, improperly balanced systems, simultaneous heating and cooling, and damaged duct and pipe insulation.

Implementation costs for correcting deficiencies identified by the study will vary with the age and condition of the systems, as well as with the quality of the original construction and past maintenance practices. Payback for the cost of the study is typically measured in months, not years.

All three of the above tools can help managers reduce the energy use of their HVAC systems, but to make those reductions permanent or the first step in actually controlling system energy use, managers must change the culture of their operations. Without a change from reactive maintenance — with its quick fixes — to one of managing system operation, any gains from these strategies will slowly fade away. The behavior of everyone involved, from the technician sent to correct an issue to the manager who oversees the department, must change. Just good enough is no longer good enough.

USEK Case

In short Retro commissioning (RCx) is a "'Tune-up' of the energy systems in an existing facility so they perform as optimally as possible AND ensure that they continue to operate optimally for the life of the facility".
While we recommend undertaking a thorough retro-commissioning process for all the HVAC system and mainly all the outdoor and indoor units, we strongly believe that the primary focus of the retro commissioning should be on the calibration of all sensors and thermostats of the related systems. This would include the normal thermostats controlling every split/DX/VRV or FCU. A proper calibration after a number of years of operation is important. Ensuring that the readings/signals that are sent to the system are correct is an important step in the objective of HVAC optimization.

USEK should devise a plan to cover throughout a time period and in phases all the thermostats and sensors in order to ensure they are properly reacting to changes in setting. The existence of the two BMS helps substantially reviewing Blocks F and H but the work should include all Blocks and all type of cooling systems.

- ➔ The potential savings can be easily in excess of 3% on the cooling system or more than 70,000KWh annually which will bring in around $10,000 of cost savings.
- ➔ The investment needed for the Retro-commissioning work is related to the contractor's /commissioning company which in the case of USEK should normally be Khater Engineering who originally installed all VRVs and the 2 BMS units. The expected payback of such a work should be less then 2 years.
- ➔ Retro-commissioning will also ensure the USEK team are trained in a way to apply a continuous commissioning as part of their maintenance practices in the future in order to ensure all systems are optimized at any given point of time.

Table 20: Retro-commissioning of HVAC system in USEK

Measure Description	Budget	KWh savings	Cost saving	Payback Period
Retro-commissioning of HVAC System	$20,000	70,000	$10,060	2

5.1.5 Employee and Student Engagement

Sustainability is becoming a 'must do' concept in the corporate world generally and more particularly in an educational campus. The cornerstone of a sustainable operation is an appropriate employee and student engagement.
In fact, a large number of studies showed that occupants' (employees /students) behavioral changes have the highest rate of return among any energy efficiency program.
The road ahead will be through a comprehensive awareness program and an alignment between all departments on utilities management issues. Employee and student engagement can be tackled through a variety of programs from educational training to visuals (posters, stickers) and online tools. Furthermore, it is always a positive point to establish and recognize one or more Energy Champions every year. An Energy Champion

- Could be anyone who sets a good example for others
- Promotes energy conservation and efficiency every day
- Responsibility is to:
  - Instill a culture of energy conservation within their respective workspaces with each occupant and with every piece of equipment.
  - Develop conservation strategies specific to their work areas.
  - Identify and implement Energy Conservation Measures (ECMs)
  - Assure there is no backsliding – Savings must be maintained.
  - Share progress, lessons learned, and innovative energy practices with other team members.

One particular example in USEK is to focus on the engagement of offices and cooled spaces occupants in terms of setting the thermostats specially when the cooling systems are of the split units or DX types which are not controlled by the BMS.A setback temperature by 2 degrees will have a substantial impact on the operation and energy consumption of the cooling units specifically and other electrical loads generally. Through a comprehensive campaign – including Block F (Dorms) , such a scheme will easily provide a 100,000 KWh savings from the total campus energy consumption

Table 21: Retro-commissioning of HVAC system in USEK

Measure Description	Budget	KWh savings	Cost saving	Payback Period
Employee/Student Engagement	$10,000	100,000	$13,060	0.13

5.2. EEM 2: Lighting Retrofit-LED Retrofit

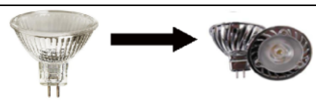
USEK's lighting energy cost represents 29% of the total annual energy cost which is in excess of $122,444 per year. Accordingly, any substantial reduction on the lighting loads' energy consumption would lead to large impact on the total facility's energy and power demand. As previously seen, the overall lighting system of the facility is mostly comprised of PL/Halogen and linear fluorescent.

Based on the field audit and energy analysis, it was seen that the largest opportunity of cost savings on lighting would be through lighting retrofits.
Generally, lighting retrofits' concept is based on introducing different new lighting technologies in the existing facility; In addition to substantial savings in the energy consumption, retrofits have also a major benefit in both the luminance and comfort. Lighting retrofit provides a major opportunity for the facility to reduce its overall lighting load while improving dramatically the overall lighting infrastructures.

The key advantages and benefits of LED lights are known to USEK as used extensively in some areas in the facility and can be summarized by:

1. *Energy Efficiency*: LED lights are very energy efficient and consume less than half the electricity of the conventional lighting technologies currently used in the branches.
2. *Good color rendering*: Good quality LED lights have excellent color rendering
3. *Long Life Cycle*: Good quality LED lights use high power LED light sources developed with a design life of over 50,000 hours which make them very reliable and reduce maintenance costs.
4. *No Mercury:* LED lamps are not fragile, require little maintenance and do not contain harmful or hazardous chemicals associated with some other low energy lighting products.

You will find here below the key LED retrofit schemes proposed along the full BOQ and pricing.

Area Example	Retrofits Suggested
T8 18W/36W and T5 28W in classes and offices  	 **Replace T8 Fluorescent by T8 LED , 4000K,120 deg** **T8 18W 60cm by T8 LED 9W 900 lm.** **T8 36W 120 cm, by T8 LED 18W 1800 lm** **T8 58W by T8 22W** **T5 28W by T5 14W**
Hal 70W and Hal 50W  	 **Replace the MR16 50W halogen by LED MR 16 4x1W Lux>320, 2500K.**
PL 58W in most offices 	 **Replace PL 2x55W by LED Square panel 36W**

Important Note on maintenance:

One of the important features of LED lighting retrofit program is its exceptional impact on maintenance costs. In fact with a life span between 30,000 hrs and 50,000 hrs. LED panels and bulbs would save a large amount on the maintenance costs of a facility as existing bulbs will be replaced 5 to 8 times before the LED are replaced. Annual maintenance savings would come from both bulbs and labor costs. Accordingly, we have considered a conservative $1 savings per year on every T8/T5 fluorescent replaced and $1 for every MR16 replaced.
It is also crucial to note that the benefits of the reduction in cooling loads and the related energy costs are excluded from the calculation – although it should be noted they could have a substantial impact as LED lighting have a much colder operation compared to fluorescent and halogen lights.

Implementing all the above retrofits throughout the facility would lead to substantial energy and cost reductions. The below table provides the financial indicators of this EEM.
Savings reach 55% of the total lighting energy consumption and 16% from the total electrical energy consumption.

Table 22: Lighting Retrofit project-LED Retrofit project

Description	Retrofit with	Qty	Unit Price	Total Cost	KWh Savings	Cost Savings	Simple Payback
Fluo T8 18W	LED T8 9W	141	$15	$2,115	3,026	$393	5.38
Fluo T8 36W	LED T8 18W	338	$22	$7,436	14,139	$1,838	4.05
Fluo T8 2x18W	LED T8 2x9W	9	$30	$270	702	$91	2.96
Fluo T8 4x18W	LED T8 4x9W	683	$60	$40,980	80,489	$10,464	3.92
Fluo T8 2x36W	LED T8 2x18W	378	$44	$16,632	55,115	$7,165	2.32
Fluo T8 4x36W	LED T8 4x18W	108	$88	$9,504	27,004	$3,511	2.71
Fluo T8 2x58W	LED T8 2x22W	296	$64	$18,944	52,733	$6,855	2.76
Fluo T5 28W	LED T5 14W	1,981	$9	$17,829	78,163	$10,161	1.75
Hal 50W	LED 4W	216	$11	$2,376	4,707	$612	3.88
Hal 70W	MR16 6W with fixture	1,135	$18	$20,430	98,085	$12,751	1.60
PL 26W	LED Panel 11W	416	$27	$11,232	9,515	$1,237	9.08
PL 2x26W	LED Panel 14W	1,192	$35	$41,720	100,024	$13,003	3.21
PL 58W	LED Panel 36W	654	$80	$52,320	17,611	$2,289	22.85
E27 23W	LED 4W	119	$11	$1,309	2,130	$277	4.73
2D 36W	LED Panel 11W	78	$27	$2,106	5,607	$729	2.89
Economy 2x23W	LED Panel 14W	200	$35	$7,000	14,760	$1,919	3.65
Economy 36W	LED Panel 11W	29	$27	$783	1,866	$243	3.23
Economy 2x36W	LED Panel 14W	108	$35	$3,780	31,761	$4,129	0.92
MH 400W	Flood Light 100W	42	$120	$5,040	47,857	$6,221	0.81
PS 250W	Flood Light 50W	40	$60	$2,400	31,200	$4,056	0.59
Inc 100W	LED bulb 4W	34	$11	$374	6,495	$844	0.44
LED Lighting Retrofit project				**$264,580**	**682,987**	**$88,788**	**2.98**

(*) Payback period calculated excluding any maintenance cost savings.

➔ -building F- 78 halogen fixtures 2x300W each are installed in the kitchens of the dorms. It is impossible to retrofit the bulb only. It is recommended instead to retrofit the whole fixture.

5.3. EEM 3: Occupancy sensors for lighting and cooling system control

5.3.1 Introduction

Lighting Control's concept is based on introducing new lighting control technologies in the existing lighting system. It provides a major opportunity for any facility to reduce its overall lighting energy consumption.

Lighting control examples are:

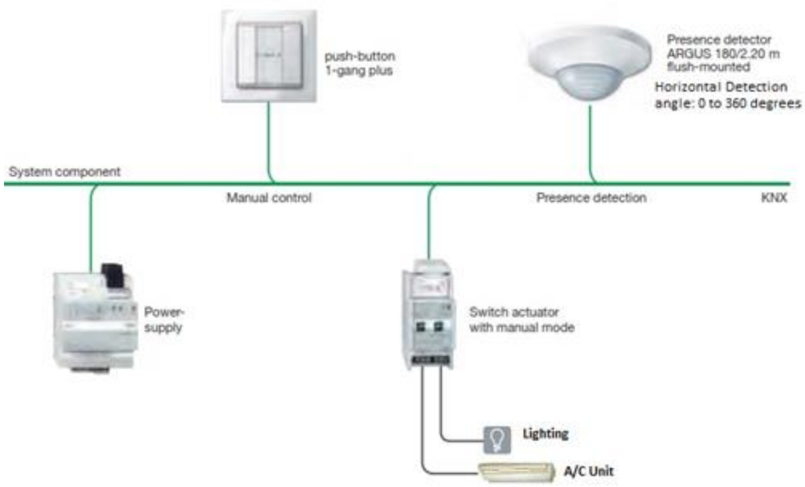
1. Time control
2. Daylight control
3. Occupancy control

The suggested lighting control for USEK is the occupancy sensors which will ensure bypassing any human error in terms of lighting and HVAC control. below is an example of coverage of the 360° sensor along the laboratory area.

Figure 33: Motion detector coverage area (Left); Laboratory in building H

the manual control in every targeted area/room will be kept but a presence/occupancy sensor will be installed in parallel and will ensure any human motion is detected over a line range of 6m with an angle 0 to 360°C. This detector will control a dual switch unit controlling both the lighting circuits and indoor cooling unit. below is a schematic of the installation.

Figure 34: Occupancy sensor installation for lighting and cooling control



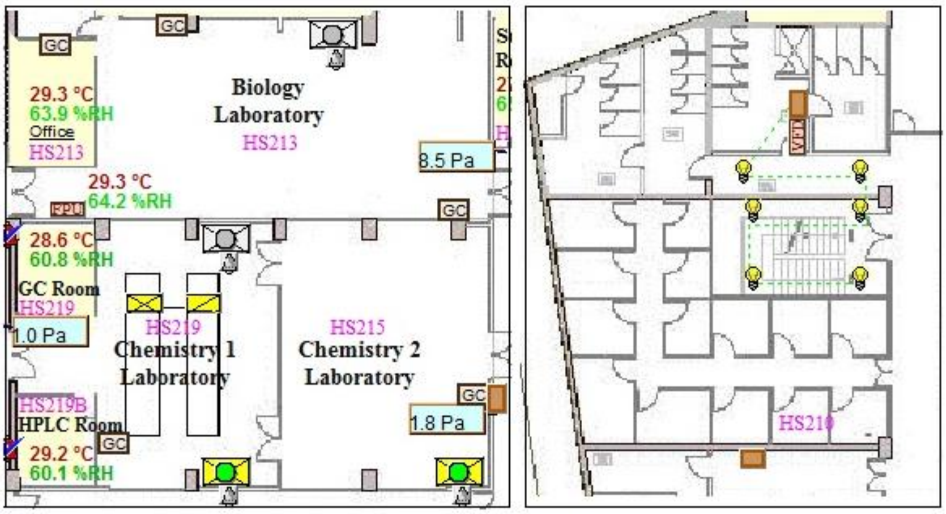
5.3.2 USEK Case

As per the energy breakdown in section 4, cooling loads consume 2,564,474KWh annually which represents 59% of the total energy consumption while lighting consumes 29% of the total energy in USEK. Accordingly, a properly applied motion detector will ensure maximizing the control of both the lighting and cooling units.

Motion sensors will shut the controlled lights and cooling units OFF when the space is vacant and will put them ON when they sense a human presence. Typically motion sensors can provide more than 20% energy savings in areas that are partly unoccupied during the day.
Their installation is rather easy and usually, the objective is to control 70% to 85% of the total lighting fixtures and cooling units of the controlled area. Based on a physical survey, it was found that class rooms, administration offices, laboratories and parking are a good opportunity for this EEM.

Figure 35: Operational cooling and lighting in unoccupied areas

Figure 36: Laboratories in the second basement of block H (Left); Administration offices (Right)



As an example for this application, we have taken the areas here above to showcase the potential installations. In the biology laboratory we can install two sensors due to the laboratory areas dimensions and shape, on the other hand, all administration offices can be covered with one sensor per office due to the limited areas.

5.3.3 Energy savings for motion detector installation

Applying this measure will have a good return on investment due to the relatively small budget and high potential savings. In fact, it is estimated – as per similar facilities, that the potential energy savings reductions are almost 25% energy savings on the controlled lighting energy consumption and 18% savings on cooling energy consumption.
The below table provides the present EEM's annual savings:

Table 23: Lighting and cooling Energy Savings-USEK

EEM Description	Lighting Energy Savings (KWh)	Cooling Energy Savings (KWh)	Total Energy Savings (KWh)	Total Cost Savings ($)
Occupancy sensors installation in Block H	39,752	36,987	76,739	$9,976
Occupancy sensors installation in the rest of the campus	133,394	226,666	360,060	$46,808
Total	**173,146**	**263,653**	**436,799**	**$56,784**

Here after is a table providing the financial key indicators of this project showing cost savings exceeding $56,784 per year which are about 10% savings on the total energy consumption of USEK.

Table 24: Occupancy sensor project key financial indicator

EEM Description	Qty	Unit Price ($)	Total Cost ($)	Total Energy Savings KWh	Cost Savings ($)	Simple Payback
Occupancy sensors with A/C breaker in block H	205	$100	$20,500	76,739	$9,976	2.05
Occupancy sensors with A/C breaker in the rest of the campus	470	$100	$47,000	360,060	$46,808	1
Total	**675**	**$100**	**$67,500**	**436,799**	**$56,784**	**1.19**

5.4. EEM 4: Retrofit Split Units with DC Inverter technology

USEK has a mixture of VRV units, DX units, Split units and chillers. While VRV are considered energy efficient and chillers have been recently installed and do not have a high load factor, the focus should be in upgrading the split units that were seen to represent by far the largest installed capacity and energy end use among the cooling systems. The below measure should be seen as a plan to be implemented in a phased approach.

5.4.1 What is a DC inverter technology?

An "inverter" is a power conversion circuit that electronically regulates the voltage, current and frequency of products such as air conditioners. This circuit controls the compressor and, therefore, the air conditioners output. Raising the frequency increases the output, while lowering the frequency reduces it. In this way, inverter air conditioners provide much finer temperature control than conventional models can.
DC inverters provide a range of benefits over conventional start/stop systems. These include:

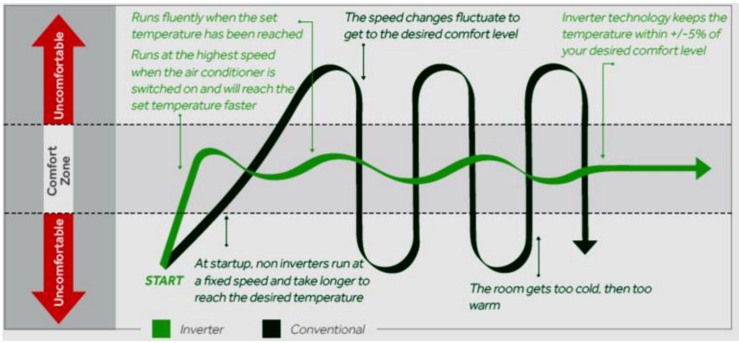
- Significantly lower running costs compared with conventional systems.
- Quickly and efficiently adjust the room temperature to the user's set comfort zone.
- Elimination of temperature fluctuations associated with traditional start/stop systems.

- Greatly reduced system noise both inside and outside the space.

Apart from its significantly reduced running costs, inverter technology has two distinct comfort advantages over conventional air conditioners:

1- Whether cooling or heating, it will reach the selected "Comfort Zone" more quickly as shown in the graph below.
2- It can then maintain operating temperatures within the "Comfort Zone" at all times, which conventional air conditioners are unable to do – also as seen in the graph below.

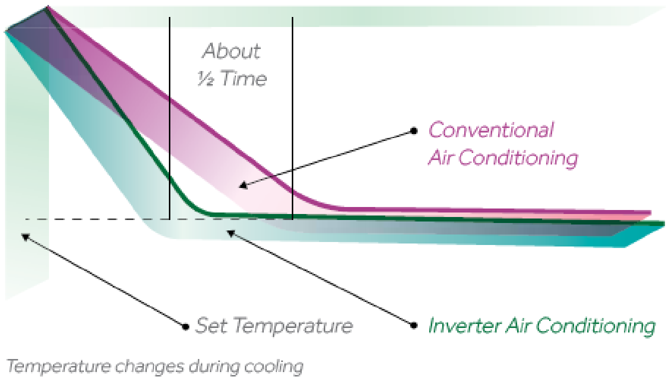
Figure 37: DC inverter and conventional split units' comparison



A major feature of DC inverter air conditioning is its retrofit capability, enabling its integration into virtually any building, old or new, with the minimum of structural alteration or disturbance to the daily routine of the staff.

When an inverter air conditioner is switched on, it supplies the exact power needed to heat or cool the room rapidly. This enables the air conditioner to reach the set temperature in around half the time required by conventional models. Air conditioning noise levels inside and outside the home are dramatically reduced by DC inverter systems because they always seek the lowest operating level, while providing the maximum heating or cooling effect.

Figure 38: DC inverter and conventional split units' temperature variation



5.4.2 DC inverter electrical savings calculation

The savings calculation is based on retrofitting the split units installed in classes and offices by a DC inverter technology with a COP more than 3.88 which would make the efficiency improvement over 40%. The first step is to calculate the present cooling energy that has been produced annually by the split units – as per the energy balance of the present energy audit, then to turn this cooling energy back to electrical energy based on the new units' efficiency.

Table 25: Split units installed and related energy consumption

Name	Description	No. of Units	Total Input Capacity (KW)	Electrical Energy Use ($KWh_{electrical}$)	Cooling Energy Needed ($KWh_{thermal}$)
Bloc A					
AC 18000Btu	Bloc A-Music	8	15.2	23,972	64,724
AC 24000Btu	Bloc A-Music	38	98.8	151,742	409,703
AC 12000Btu	Bloc A-Music	62	80.6	123,790	334,233
AC 28000Btu	Bloc A-Music	14	42	62,681	169,239
AC 9000Btu	Bloc A	11	11	16,388	44,248
Bloc B					
AC 24000Btu	Bloc B	51	132.6	240,158	648,427
AC 18000Btu	Bloc B	3	5.7	10,803	29,168
AC 12000Btu	Bloc B	21	27.3	50,676	136,825
AC 28000Btu	Bloc B	4	12	22,275	60,143
Bloc H					
AC 12000Btu	Bloc H	12	15.6	10,262	27,707
AC 24000Btu	Bloc H	2	5.2	3,421	9,237
AC 18000Btu	Bloc H	1	1.9	1,276	3,445
AC 9000Btu	Bloc H	1	1	638	1,723
Bloc C					
AC 28000Btu	Bloc C	13	39	57,252	154,580
AC 32000Btu	Bloc C	6	20.4	30,388	82,048
AC 12000Btu	Bloc C	18	23.4	34,351	92,748
AC 24000Btu	Bloc C	29	75.4	110,687	298,855
Bloc D					
AC 12000Btu	Bloc D	10	13	9,360	25,272
AC 24000Btu	Bloc D	22	57.2	38,370	103,599
AC 9000Btu	Bloc D	5	5	3,253	8,783
AC 28000Btu	Bloc D	5	15	10,062	27,167
AC 32000Btu	Bloc D	11	37.4	25,457	68,734
AC 18000Btu	Bloc D	4	7.6	5,205	14,054
Bloc E					
AC 9000Btu	Agronomy	3	2.91	2,386	6,442
AC 12000Btu	Agronomy	11	14.3	11,723	31,652
AC 24000Btu	Agronomy	21	54.6	44,979	121,443
AC 18000Btu	Agronomy	3	5.7	4,795	12,947
AC 28000Btu	Agronomy	12	36	29,513	79,685
AC 32000Btu	Agronomy	1	3.4	2,828	7,636

Name	Description	No. of Units	Total Input Capacity (KW)	Electrical Energy Use ($KWh_{electrical}$)	Cooling Energy Needed ($KWh_{thermal}$)
Block G					
AC 18000Btu	Block G	7	13.58	14,399	38,877
AC 9000Btu	Block G	12	11.64	12,341	33,321
AC 24000Btu	Block G	2	5.2	5,514	14,888
AC 12000Btu	Block G	12	15.6	16,606	44,836
Block I					
AC 10Tons	Sports Club	1	12.9	15,964	43,102
AC 24000Btu	Sports Club	2	5.2	6,435	17,375
Total				**1,209,950**	**3,266,864**

The table here after provides the comparison of the electrical energy consumption needed to produce the same cooling energy between the existing split units with the COP of 2.7 and the DC inverter with the COP of 3.88.

Savings attained are 30% from the present conditions and represent about 8.5% of the total electrical energy consumption of USEK with an annual reduction of around 367,973KWh and a related cost reduction of $44,893 per year.

Table 26: Comparison of electrical energy consumed to produce the cooling capacity needed

Location	Split Units Energy Consumption (KWh)	DC Inverter Energy Consumption (KWh)	KWh Savings	Cost Savings ($)
Block A	378,573	263,440	115,133	$14,046
Block B	323,912	225,403	98,509	$12,018
Block C	232,678	161,915	70,763	$8,633
Block D	91,707	63,817	27,890	$3,403
Block E	96,224	66,960	29,264	$3,570
Block G	48,860	34,001	14,859	$1,813
Block H	15,597	10,854	4,743	$579
Block I	22,399	15,587	6,812	$831
Total	**1,209,950**	**841,977**	**367,973**	**$44,893**

below is the table providing the key financial indicators of the DC inverter technology installation based on an installed cost of $750 per unit.

Table 27: DC inverter technology Project Key Financial Indicators

EEM	Quantity	Unit Price ($)	Total Cost	KWh Savings	Cost Savings ($)	Simple payback
DC Inverter Technology	438	$650	$262,800	367,973	$44,893	5.8

The choice of the DC inverter split units is further reinforced by the fact that the copper piping don't need to be changed and accordingly the installation will be easily done.

5.5. VRF Retrofit for the DX units in USEK (What If Scenario)

The main objective of this exercise is to showcase the “what if” scenario in case USEK has opted for a centralized cooling system for the areas cooled via DX units. Due to the large DX capacity units installed with a COP not exceeding 2.7, the current system is not ideal for the operation of many zones such as the library, the theatre, the cafeteria… the best solution would have been to focus on a higher performance technology with large capacities and greater energy saving .

5.5.1 What is a VRF system?

Widely acknowledge as the most advanced system, VRF represents a powerful combination of advanced inverter and heat pump technologies. VRF can switch from cooling to heating or supply both at the same time to different parts of the building. In its heat recovery format, heat exhausted from indoor units in the cooling cycle is merely transferred to units in areas requiring heat, maximizing energy efficiency, reducing electricity cost and leading to part load efficiencies up to 9.

A major feature of VRF air conditioning is its retrofit capability, enabling its integration into virtually any building, old or new, with the minimum of structural alteration or disturbance to the daily routine of the staff. Also since the system is intended to be “neither seen nor heard” its refrigerant piping can be concealed without undue difficulty and its indoor units are designed to blend with interior decors of all styles and ages. The selection of VRF air conditioning is aimed at providing rapid return on investment and to provide a high grade indoor environment at low running costs.

The running costs of VRF system are low because it allows each zone to be controlled individually. That is only those rooms which require air conditioning will be cooled while system can be shut down completely in rooms where no air conditioning is required. Thanks to inverter technology, the outdoor units can be easily adjusted to the total load.

5.5.2 VRF System Electrical Savings Calculation

The savings calculation is based on retrofitting the DX units in different areas in USEK by a VRF system with COP more than 4,5. The area we focused at is classes and offices. The table below shows the existing DX units installed and the related cooling capacity.

Table 28: Cooling capacity needed

Type	Location	Quantity	Unit $KW_{cooling}$	Total $KW_{cooling}$
Block A				
AC 3Tons	Block A-Music	15	10.55	158.25
AC 5Tons	Block A	9	17.59	158.27
AC 36000Btu	Music	4	10.55	42.20
AC 48000Btu	Music	4	14.07	56.27
Block B				
AC 5Tons	Block B	1	17.50	17.50
AC 32000Btu	Block B	2	9.38	18.76
AC 3Tons	Block B	1	10.55	10.55
Server Room				
AC 15Tons	Server room	2	52.70	105.40
AC 10Tons	Server room	1	35.17	35.17
Block D				
AC 38000Btu	Block D	1	11.14	11.14
AC 3Tons	Block D	9	10.55	94.95
Block E				
AC 48000Btu	Cafeteria	6	14	84
AC 40000Btu	Theatre	4	11.72	46.88
AC 3Tons	Theatre	1	10.55	10.55
AC 36000Btu	Faculty of Agronomy	1	10.55	10.55
AC 4Tons	Faculty of Agronomy	3	14.00	42.00
AC 5Tons	Faculty of Agronomy	6	17.58	105.48
Total				**1,007**

The rating DX cooling capacity needed is 1,008KW. The table below shows the comparison between the rated electrical power that must be installed to produce 1,008$KW_{cooling}$ via VRF system and the installed DX capacities to produce the same cooling capacity. The calculation is based on COP of 2,7 for the DX units and a COP of 4.5 for the VRF system.

Table 29: Comparison of the electrical rated power to produce the cooling capacity needed

	$KW_{cooling}$	Rated DX $KW_{electrical}$	Rated VRF $KW_{electrical}$
Block A	415	145.5	92.2
Block B	46.81	17	10
Server Room	140.6	46.6	31.2
Block D	106	39.2	23.5
Block E	158	58.5	35.1
Theatre	57.43	19.5	12.76
Cafeteria	84	31.2	18.6
Total	**1007.84**	**357.5**	**223.36**

The electrical power installed will be reduced by134KW electrical. The table here after shows an estimated calculation for the savings of the VRF system. The savings can reach about 177,000 KWh per year related to $23,022 of annual cost savings.

However, the CAPEX of related VRF units with a total capacity of 285RT will be in excess of $500,000 leading to a non viable payback period. Accordingly, we recommend replacing every set of DX units or a combination of sets of DX units by a VRF when the related maintenance costs become high and/or units are close to the end of their life cycle.

Table 30: Estimated energy savings if installed VRF

Location	Electrical Energy Consumption (KWh)		Energy Savings (KWh)	Cost Savings ($)
	DX Units	VRF System		
Block A	222,211	140,032	82,179	$10,683
Block B	31,612	18,573	13,039	$1,695
Server Room	123,530	82,706	40,824	$5,307
Block D	26,174	15,721	10,453	$1,359
Block E	49,255	29,754	19,501	$2,535
Theatre	6,331	4,134	2,197	$286
Cafeteria	22,048	13,150	8,898	$1,157
Total	**481,161**	**304,070**	**177,091**	**$23,022**

5.6. EEM 6: Waste Heat Recovery

5.6.1 Waste Heat Recovery Definition

Waste Heat, in the most general sense, is the energy associated with the waste streams of air, exhaust gases and/or liquids that leave the boundaries of a plant or building and enter the environment. In other terms, waste heat is that energy, which is rejected from a process at a temperature high enough above the ambient temperature to allow the economic recovery of some fraction of that energy for useful purposes. All waste heat that is successfully recovered directly substitutes for purchased energy and therefore reduces the consumption and cost of that energy. A second potential benefit is realized when waste heat substitution results in smaller capacity requirements for energy conversion equipment.

5.6.2 Heat Rejected from generators

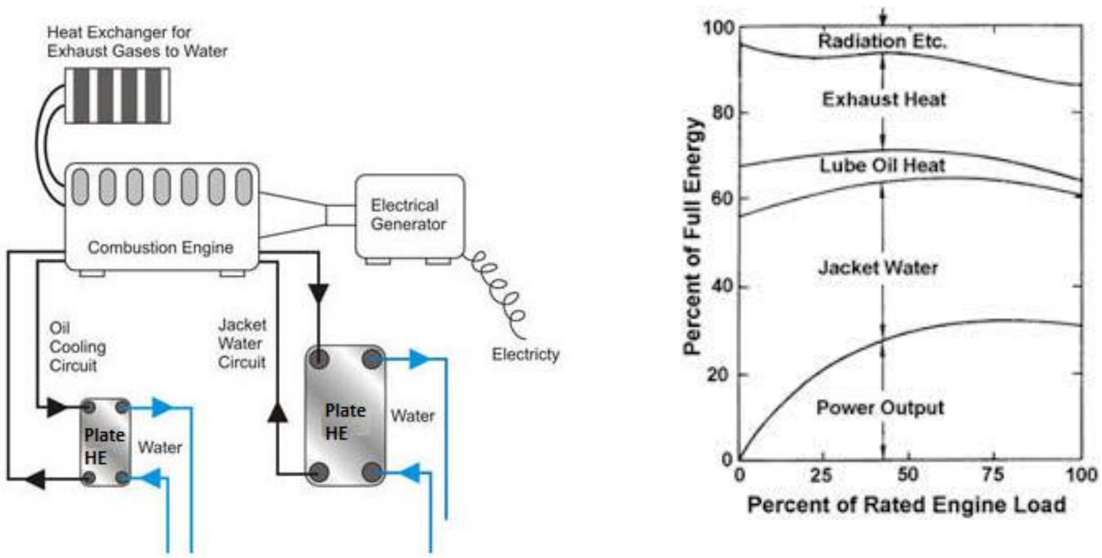
Heat recovery on an engine refers to the capture and reutilization of heat energy which is normally wasted to radiators. This process increasingly common today, improves total system efficiency and return on investment. New plants designed for this purposes are called cogeneration plants. Reciprocating engines energy coming from fuel is converted to:

- 30-40% mechanical power
- 20-40% rejected to the jacket water
- 30-40% rejected to exhaust
- 5-7% radiated to the environment

Generally, these data depend on the type of engine and manufacturer.
While the heat rejected by the jacket water can be relatively totally recovered , one can recover only 50-70% of the exhaust rejected energy due to problem of low temperature of exhaust and corrosion resistance of heat exchangers

below is a simplified schematic of the engine's heat recovery along with the various energy content streams of the engine versus the load and here below a general

Figure 39: Engine Heat Recovery connection (Left) , Engine Energy Balance v/s Load (Right)



5.6.3 USEK Case: Hot water from Jacket water coolant

The facility has six generators 1000kVA each and two generators 700kVA each that are running on a need basis during power failure. Accordingly, there is a substantial amount of thermal energy that can be recuperated and used for hot water production.
Normally, USEK could benefit from the heat recovery of both the jacket water cooling and exhaust gas ones; however, due to the fact that the hot water demand is limited in the campus and that is currently covered in its majority by solar thermal in the dorms, then the jacket water heat recovery is enough to fulfill all the demand.
At the present stage the economical assessment is not possible as the savings are those related to the diesel consumed in both boilers in the dorms and which data is not available.
In any upcoming campus expansion, USEK can also consider this thermal energy source in its original plans.

In order to calculate the potential thermal energy recovered, we have as a first step to get the generators' heat rejected conditions at full load and then work out the new parameters at the average real loading. The below table provides the conditions at 100% loading for both generators type.

Table 31: Generator heat rejected Description @ full load

Type	Gen 1000kVA	Gen 700kVA
Heat Rejected to Exhaust	757kW	641kW
Heat Rejected to Jacket Water Coolant	300kW	234kW

The monthly thermal energy recovered from the jacket cooling of all generators is found in the below table. It is to be noted that the budget of heat recovery system is about $25,000 per generator and we recommend targeting the 1,000KVA ones if needed.

Table 32: Thermal energy recovered from the jacket water coolant

Month	Diesel Consumption (Liters)	Total Energy Recovered (KWh)	Total Energy Recovered (MJ)
January	8,907	168,739	607,461
February	8,713	152,410	548,675
March	9,584	168,739	607,461
April	12,433	163,296	587,866
May	18,880	168,739	607,461
June	17,677	163,296	587,866
July	41,928	168,739	607,461
August	41,923	168,739	607,461
September	18,874	163,296	587,866
October	9,583	168,739	607,461
November	9,573	163,296	587,866
December	7,011	168,739	607,461
Total	**205,086**	**1,986,768**	**7,152,365**

5.7. EEM 7: Roof Insulation-Green Roof

5.7.1 Introduction

Buildings A and B have a large land area footprint leading to a substantial roof space that exceeds 2,181m^2. It has a standard insulation cover that is still enabling large heat gains inside the buildings. Moreover, 40% of energy consumption of the campus is in these two buildings which increase the interest of energy savings in block A & B.

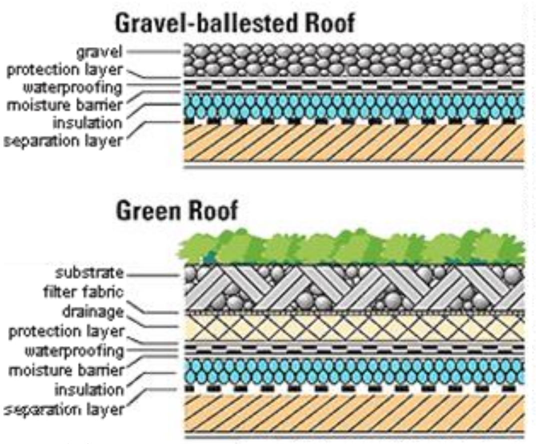
Figure 40: Roof of buildings A and B

It is therefore important to research all possible solutions that would reduce the heat gains of the roof and assist the cooling system of both buildings by reducing the cooling load.
With such a large surface, the first general idea was to install a solar thermal system. However, as the facility has no need for hot water, while solar thermal cooling will not be financially feasible, the idea was totally dropped. For informational purpose, note that the budget to cover the roof by solar panel will exceed the $250,000.
The other obvious solution is to improve the roof insulation. Adding normal gravel would help but the best solution that would provide the highest savings while providing substantial environmental benefits is the" Green Roof "concept.

5.7.2 Green Roof Concept and Benefits

A green roof is a continuous layer of vegetation and soil that covers a roof's surface. The main components are waterproofing, soil, and the plants themselves. Green roofs are an important conservation technology because they increase the energy performance of buildings, improve indoor as well as outdoor air quality, and enhance the health of urban watersheds. There are two distinct types of contemporary green roofs: extensive and intensive.

Figure 41: Gravel Roof v/s Green Roof components



An extensive green roof consists of a shallow soil profile with low-growing, horizontally spreading plants. These plants are primarily succulents that are adapted to rooftops, where there is often little water and soil but significant exposure to sunlight and wind.
Extensive green roofs usually require less structural support than intensive ones, and they are considered to be more environmentally effective.

Therefore, this publication focuses on the design and installation of extensive green roofs. All green roofs are natural systems that effectively cool the temperature of ambient air at roof level. The vegetation layer shades the roofing membrane, thus significantly reducing heat gain through the roof. The vegetation cover itself adds green space to areas that otherwise would remain impervious and uninhabitable to birds, butterflies, and other small wildlife. Green roofs are important to consider in designing a sustainable facility, especially in urban areas, because roofs make up such a large percentage of the impervious surfaces in cities. Thus, they contribute to two key problems: the "urban heat island" effect and urban storm water runoff.
Both problems affect the consumption of energy and water and the demand on energy and water systems.
Green roofs contribute to energy management and water conservation in both direct and indirect ways. They provide shade, which reduces solar heat gain through the roof by almost 100 percent and mitigates the urban heat island effect. Also, a green roof's soil and vegetation layer absorbs and filters rain, preventing it from becoming polluted runoff from the roof's surface. And the photosynthesis process in vegetation has been shown to help reduce greenhouse gas emissions.
Green roofs absorb, filter, and temporarily store precipitation. This water storage and filtration feature helps to mitigate the impacts of urban storm water runoff. Volume, peak runoff rates, and associated non- point-source pollution—primarily sediments and nutrients such as nitrogen and phosphorus— are of great concern to the health of watersheds, aquatic life, and air quality, especially in urban centers.

Figure 42: Two examples of Green Roof: In New York (Left); On the Lebanese Central Bank Roof – CEDRO project (Right)

5.7.3. Energy Saving Mechanism

Green roofs represent a unique, unconventional approach to increasing the energy performance of buildings through shading, insulation, evapo-transpiration, and thermal mass. Measurable direct benefits are lower roof surface temperatures and reduced heat transfer through the roof, which reduce peak air-conditioning and energy demand. These energy-saving properties are different in summer and winter.

Summer energy savings:
In summer, a green roof forms a protective layer over the waterproofing membrane, thereby shading the roofing system from direct ultraviolet (UV) radiation. From March to November, a chemical process occurs in plants known as photosynthesis, in which plants use the energy in sunlight to form carbohydrates from the carbon dioxide in the air and the water in the soil. Plants on a green roof thus prevent the surface of the roof from absorbing the sun's heat energy. This has a direct impact on the temperature of the indoor air immediately beneath the roof. The plenum heat gain is

reduced, and energy demand for space conditioning is correspondingly reduced. As plants take up water from soil and transport it through their leaves to the atmosphere (transpiration), water also evaporates from the soil's surface and leaves. The total water loss— evapotranspiration— helps to effectively cool ambient air temperatures at roof level. This has a significant impact on mitigating the urban heat island effect.

Winter energy savings:

In winter, plants are dormant, and neither photosynthesis nor evapo-transpiration takes place. During this season, the thin vegetation layer of an extensive green roof adds thermal mass and provides a barrier that prevents some of the warm air from escaping through the roof. Small air pockets in the soil and around the roots add insulation.

The insulation value depends on the soil's moisture content, and it decreases with greater moisture. The plants, with their various heights and surface textures, help to reduce the velocity of cold winter winds over the roof, preventing additional heat loss through the surface.

The National Research Council of Canada conducted a field study over a two-year period (2000 to 2002) to evaluate the thermal performance of green roofs. The test roof was evenly divided into an extensive green roof (green roof) and a modified bituminous roof covered with light gray gravel (reference roof).

Table 33: Normalized (per unit area) Heat Flow through the Roof Surfaces

	Reference Roof	Green Roof	Reduction
Heat Gain	5900 Btu/ft^2 (19.3 kWh/m^2)	270 Btu/ft^2 (0.9 kWh/m^2)	95%
Heat Loss	13500 Btu/ft^2 (44.1 kWh/m^2)	10100 Btu/ft^2 (32.8 kWh/m^2)	26%
Total Heat Flow	19400 Btu/ft^2 (63.4 kWh/m^2)	271 Btu/ft^2 (33.7 kWh/m^2)	47%

Source: National Research Council of Canada

The study found that the test green roof significantly reduced heat flow through the roof. It also reduced the average daily energy demand for space conditioning by 75 percent in summer. The table above shows heat gain and heat loss in total Btu per square foot. The green roof appeared highly effective in reducing heat gain in summer. It was less effective in winter, reducing heat loss an average of 26 percent, as compared with a reduction in heat transfer of 75 percent in summer.
The important notion on green roof is that comparing only the reflectivity of a green roof with that of a light-colored roof surface can be misleading when determining the more energy-efficient surface. Almost all traditional building materials, regardless of color, will transmit some heat; a green roof, however, is a live ecosystem that performs natural processes. Green roofs, though darker in color and correspondingly lower in reflectivity than light roof surfaces, do not reflect solar radiation; instead, this solar energy is used by the green roof's vegetation. Almost none of the sun's heat passes into the building. The vegetation uses the solar energy to provide effective cooling through the evapo- transpiration process described above. Also, because green roofs do not reflect solar radiation, occupants of neighboring buildings do not have to restrict reflections from them by installing additional shading.

Practical solution for Lebanon Green Roof

Due to its 6 months of sustained high solar radiations, Lebanon is a perfect candidate for effective green roofs. All the above mentioned benefits are achievable. On the other hand, economical

practical systems can be found.
Green roof would consist of the following key components:

1. Roof deck, Insulation, Waterproofing
2. Protection and Storage Layer
3. Drainage and Capillarity Layer
4. Root permeable Filter Layer
5. Extensive Growing Media
6. Plants, Vegetation

From the technical and market research, the best available plantations for green roof are Sedum plants. Sedums are very easy to propagate as almost any tiny leaf or piece of stem that touches the ground will root. In addition, those plants can resist high temperatures, require practically no maintenance and need very little irrigation (once a month is enough when there is no rain). Sedum come in various type and models (the below figure shows two examples) and cost between 7,000LL and 25,000 LL per unit in the market.

Figure 43: Two examples of Sedum Plants in a Green Roof application

USEK motives:

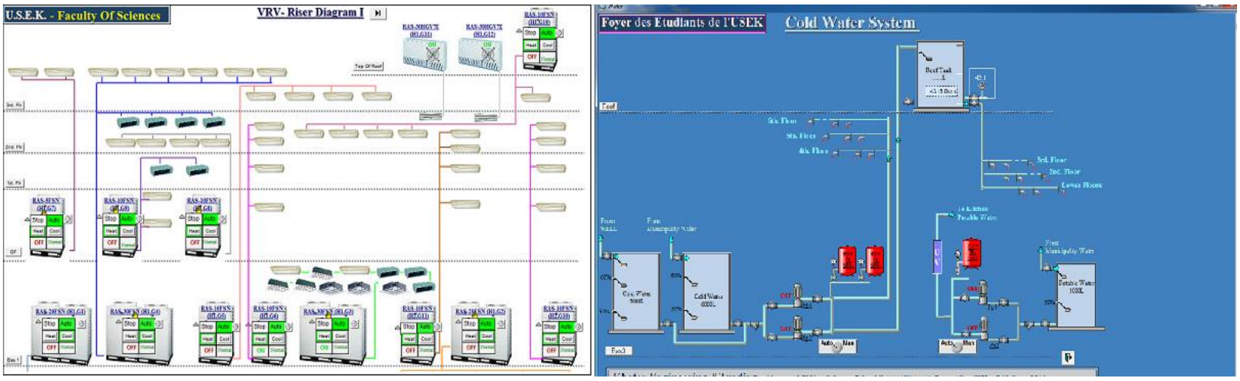
For USEK, the green roof investment should be perceived mostly from a sustainability leadership point of view as the direct energy savings to be achieved are limited to the cooling – and to a much lesser extent potential space heating of the upper floors.
However, the Green Roof project will surely have a greater impact in terms of the reduction of the Heat Island Effect in the campus and in showing the commitment of USEK to reduce its GHG emissions in line with its investments in Renewable Energy and Energy Efficiency .

5.8. EEM 8: BMS System Upgrade and Extension

It was previously seen that there are two separate BMS in USEK in Blocks F and H respectively. Both systems are well designed with a large number of functions used. However, we recommend advancing the platforms in three ways:

i. Merging the systems for a centralized Operators Management
ii. Expanding the Automation and Control of main equipment
iii. Develop Energy Dashboard and expand metering

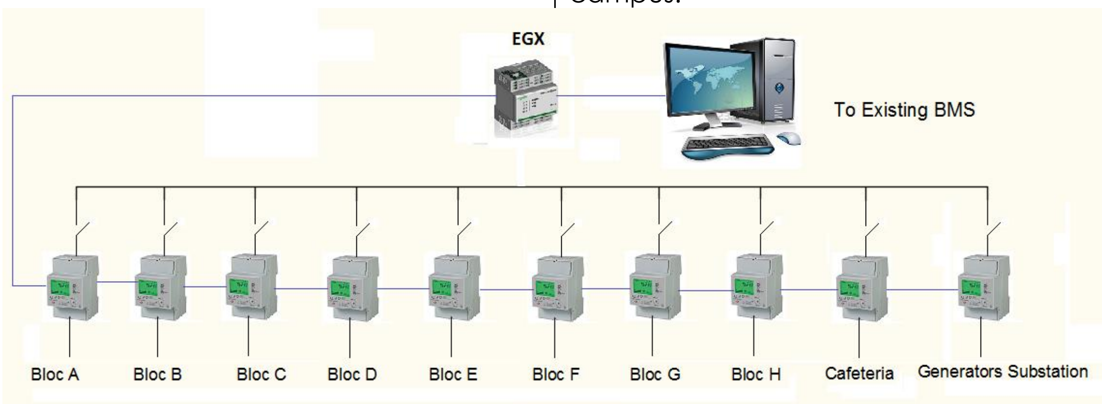
Figure 44 - Snapshot from the BMS in the block H (Left); BMS Snapshot in block F (right)



The key recommend actions are found in the below table

Action	Description
Merge BMS Platforms	A BMS will have its impact greatly improved when there is a proactive operators approach. At the present time USEK has two separate platforms requiring at any given time two operators. It is far more efficient to have one central BMS that would connect to both buildings and any future expansion. This will allow a better visualization and management of all the technical services along with assuring a good implementation of all energy efficiency procedures and automation.
Expand points of monitoring and control	Both systems are already connected to the key MEP equipment in Blocks F and H such as the VRF units, fans and boilers. We recommend extending the points in Block H to include the three McQuay chillers and their pumps. As a second phase, USEK can add connections to the VRF units and large DX units found in Blocks A and B. This will allow a centralization of all the technical management and then undertak the potential soft measures in terms of better controlling the various units.
On Site Generators	To connect all Generators' main boards to the BMS in order to have all the key parameters such as the load, operating hours, KWh , oil temperature…A diesel flowmeter could be added to track the diesel consumption of all or individual generator

Expand metering	USEK to install and connect energy meters at all key points of the campus in order to allow undertaking the detailed load and consumption allocation. The below figure is an example of how meters can be connected to the BMS via the Ethernet infrastructure of the campus.



Build Trend	All values read in the BMS can have their trends (Data recording) programmed. This should include the operations of all cooling systems (VRFs) along all metering points. Building a historical database of the campus is a very important milestone on the overall Energy Management Program and the lack of detailed data during the present energy audit is a clear example of the positive impact such a measure will have.
Energy Dashboard and Energy Reports	Once the above metering and expansion are done, USEK will need to build graphical gauges for online dashboard along customized energy reports. Dashboards could include: - Active total KVA/KW Demand for the total Campus and for each building Block - Month to date total KWh for the campus and for each Block - Month to Date KWh consumption on all EDL feeders and per tariff - Month to date KWh consumption on generators - Month to date Generators diesel consumption

The development of the BMS will enable USEK engineering operators to apply a set of control strategies leading to substantial energy consumption reduction – specially with the help of the BMS contractor in terms of expanding the automation practices. Furthermore, the energy metering , trending , reporting and dashboards will enable a proper tracking , benchmarking and goals setting which will similarly lead to a reduction of the energy usage,