Moving Towards Net-Zero Energy of Existing Building on Hot Climate

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Outline

- Background
- Introduction
- Studied Building Status and Energy Consumption
- Phase-I: Energy Conservation at Minimum Cost
- Phase-II: Energy Conservation with Investment
- Phase-III: Building Integrated Photovoltaic (BIPV)
- Concluding Remarks
- Conclusions.

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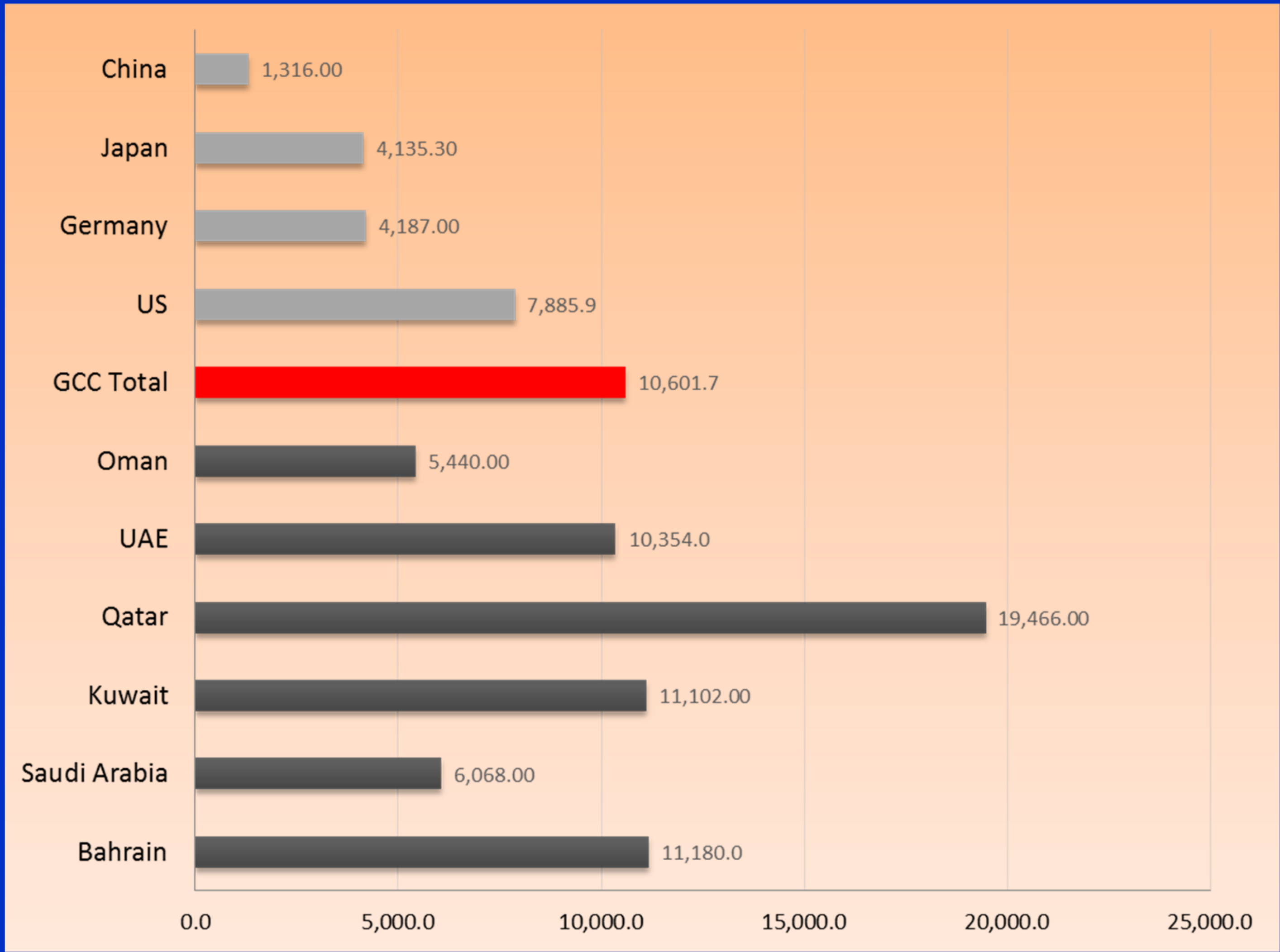
Background

- Overview of the country consumption per capita
- Overview of the country CO_2 per capita
- Definition of Net-Zero Energy Building (NZEB)
- Definition of near Net-Zero Energy Building (nNZEB)
- Why NZEB of existing building?

Energy Consumption: Annual per capita Units: kWh per person



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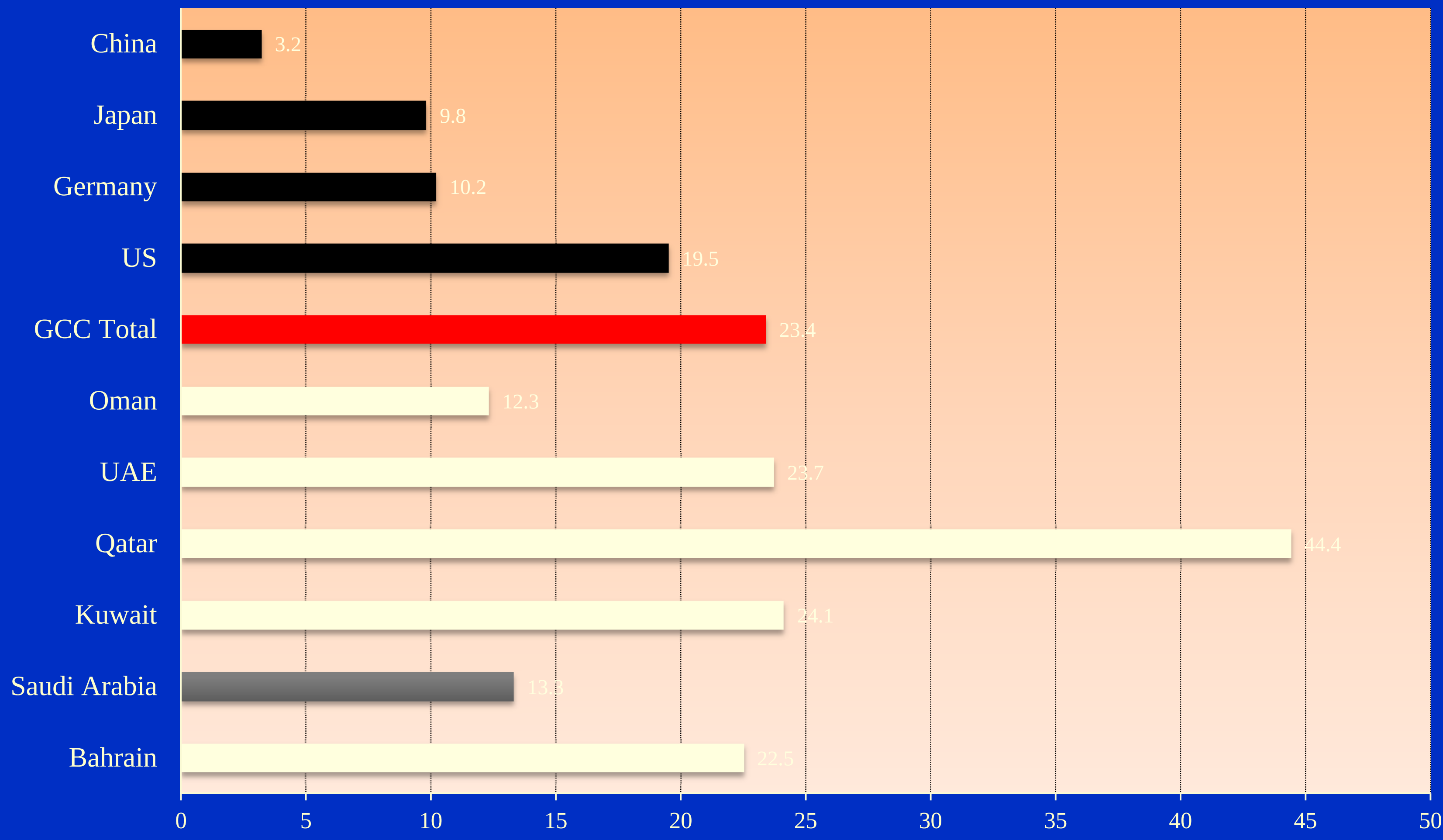
Carbon Emissions: Annual per capita Units: Metric tons of CO2 per person



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Net-Zero or near Net-Zero Energy Building

- Net-Zero Energy Buildings (NZEBs) are:

$$E_{Annual\ Renewable} = E_{Annual\ consumed}$$

- It is called near Net-Zero Energy Building (nNZEB) if:

$$E_{Annual\ Renewable} \approx E_{Annual\ consumed}$$

- European countries has issued a legislation that public buildings have to be nearly zero energy building by the end of year 2018
- ASHRAE assign a target of net zero energy buildings fulfillment by 2031

Why NZEB of Existing Buildings?

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Studied Building Status and Energy Consumption

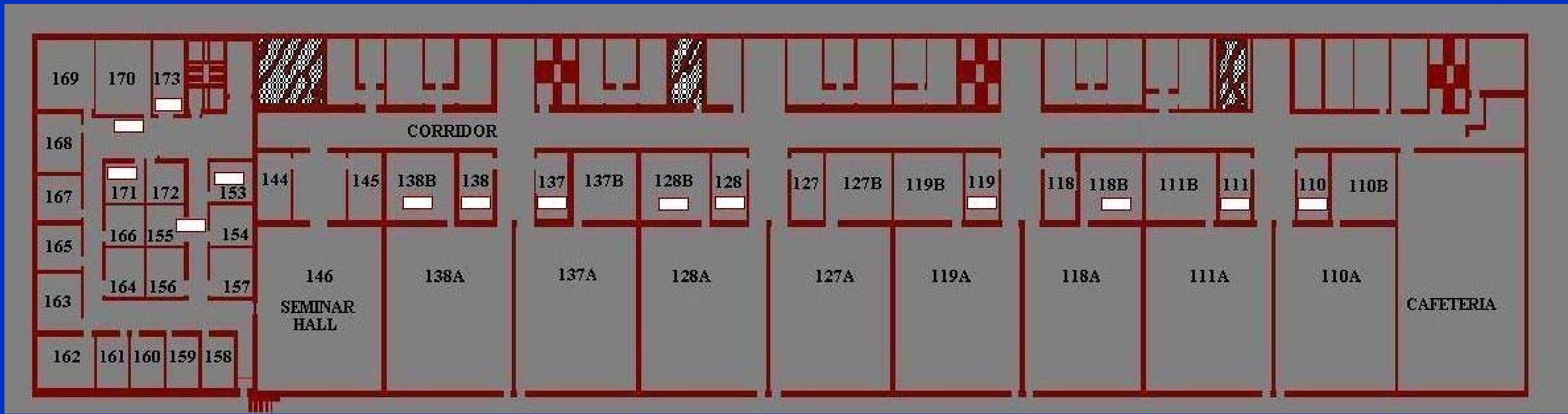
- A two-story institutional facility, that houses the Mechanical Engineering Department (MED), College of Technological Studies(CTS)
- The total floor area of 7020 square meters (offices, classrooms, laboratories, and workshops)

HVAC Description

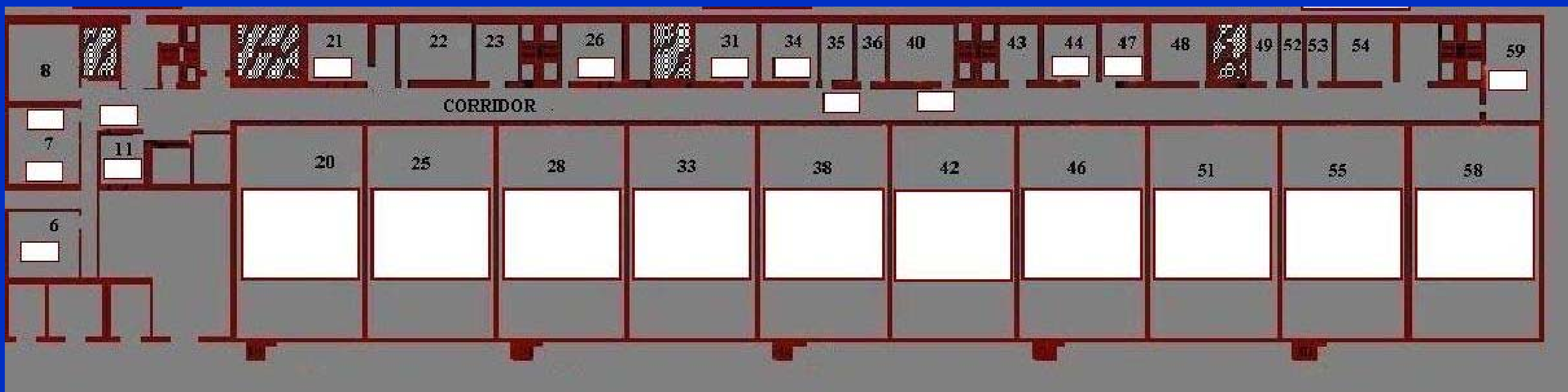
- 4 air-cooled centrifugal chillers with capacity of 429 kW (122 ton) each.
- 14 CV AHUs for offices, class rooms, and laboratories.
- 29 FCUs for the workshops

First and Ground Floors Layout

First



Ground



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Phase-I: Energy Conservation at Minimum Cost

- **Level I – Walk-Through Assessment**

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Level I – Walk-Through Assessment …cont.

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Level I – Walk-Through Assessment …cont.

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Level I – Walk-Through Assessment …cont.

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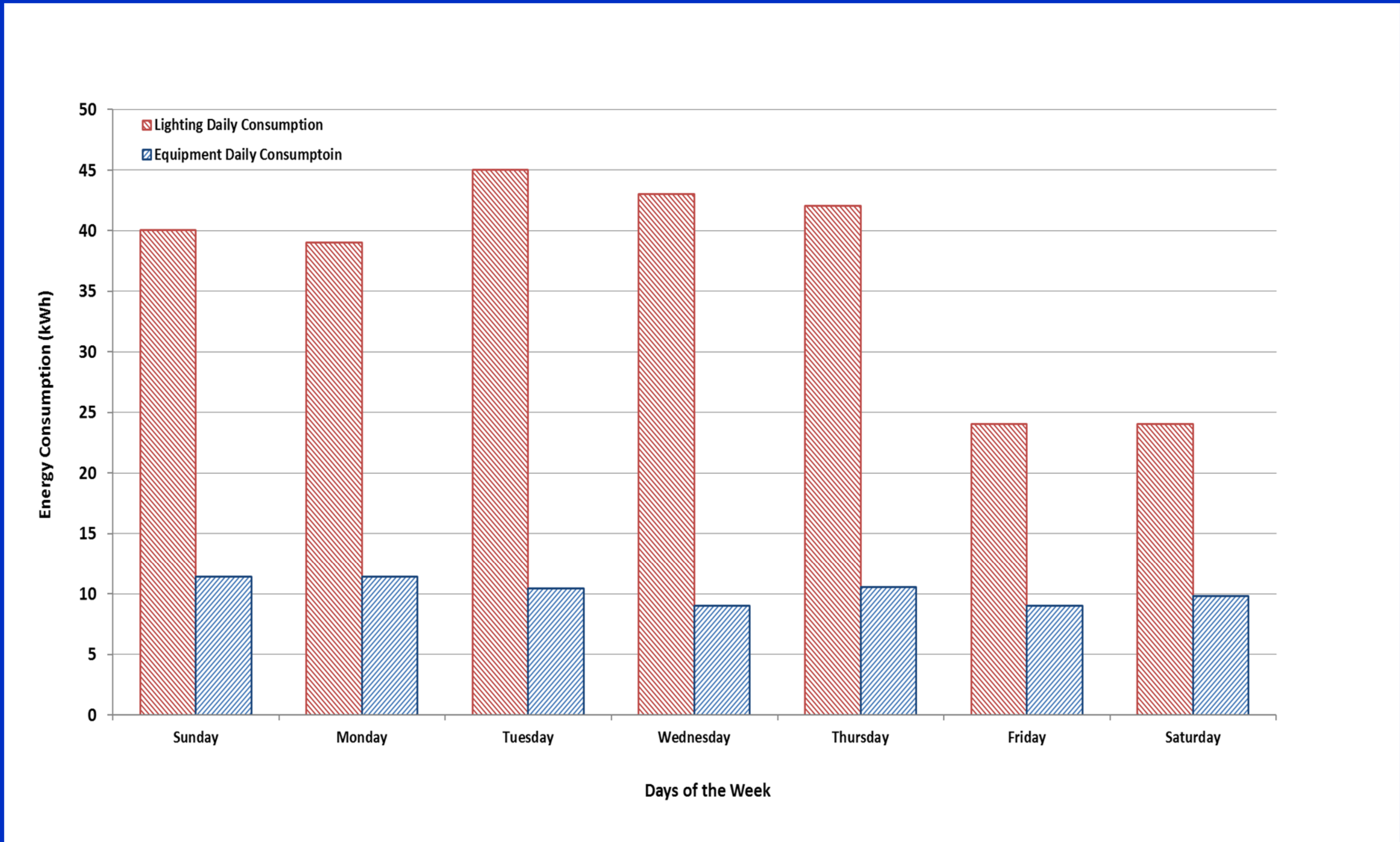
Level I – Walk-Through Assessment …cont.

Measuring Data



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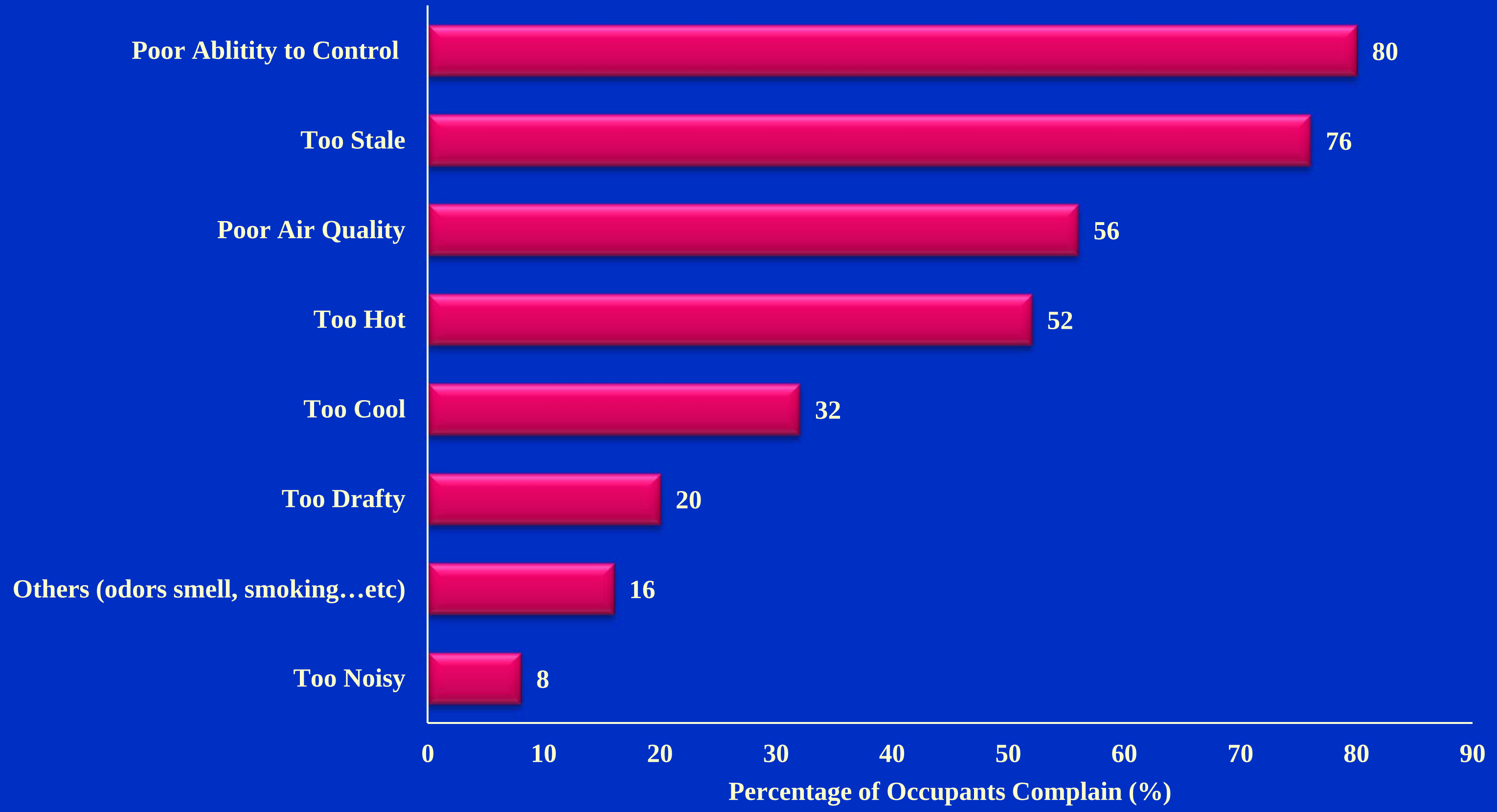
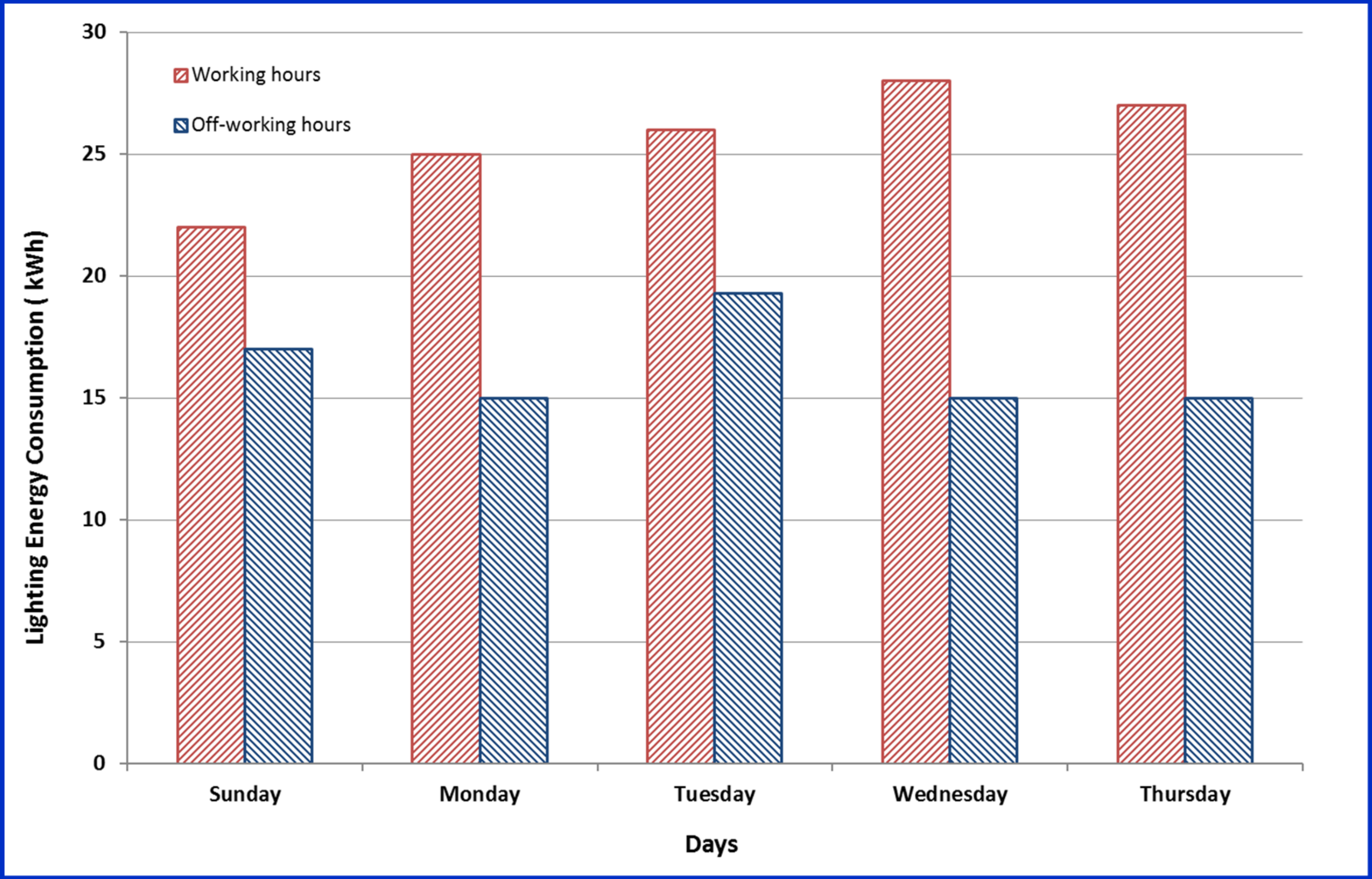
Survey Outcomes



Measuring Data



Annual Building Consumption

Building Consumptions Vs. Benchmarking

Actual Building Energy Consumption (kWh/m².year)		Typical Building Energy Consumption (kWh/m².year)*	
2008	2009	2008	2009
599	622	295	327

***Normalized to be similar to the actual building specification.**

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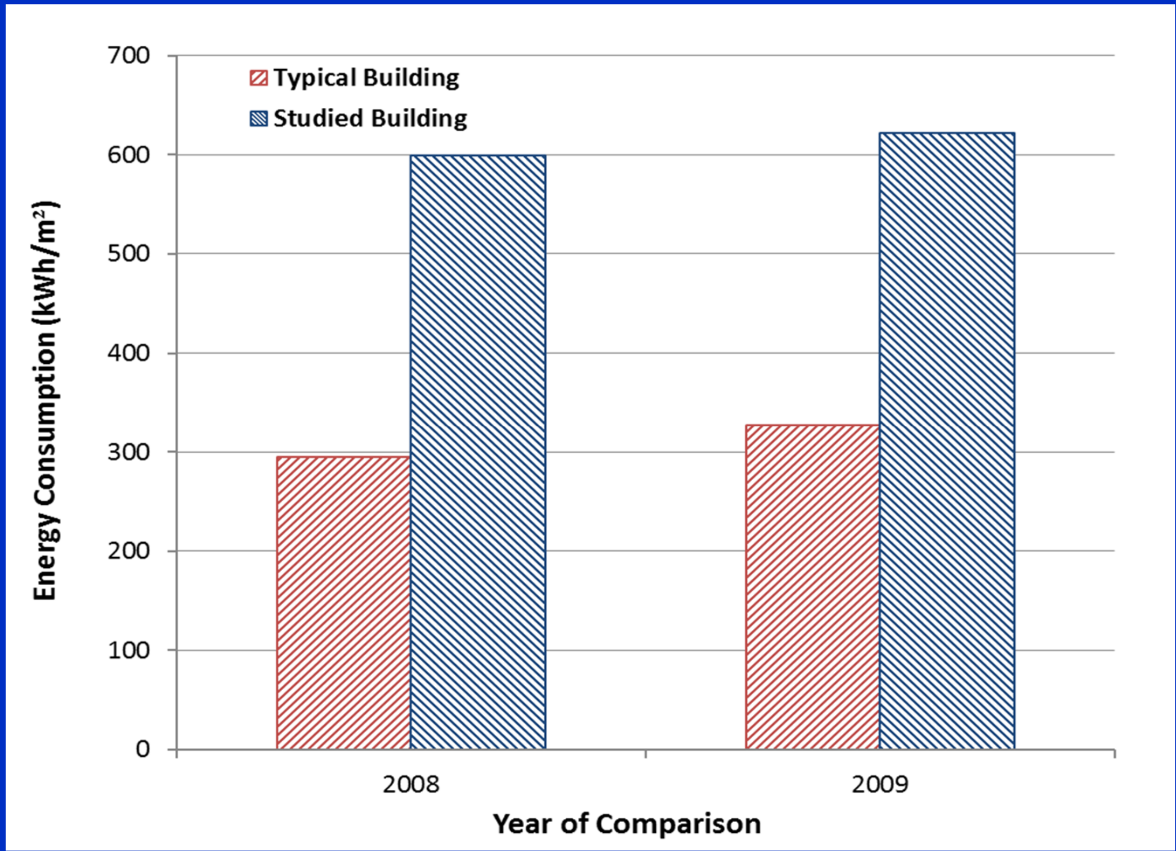
Annual Building Consumption



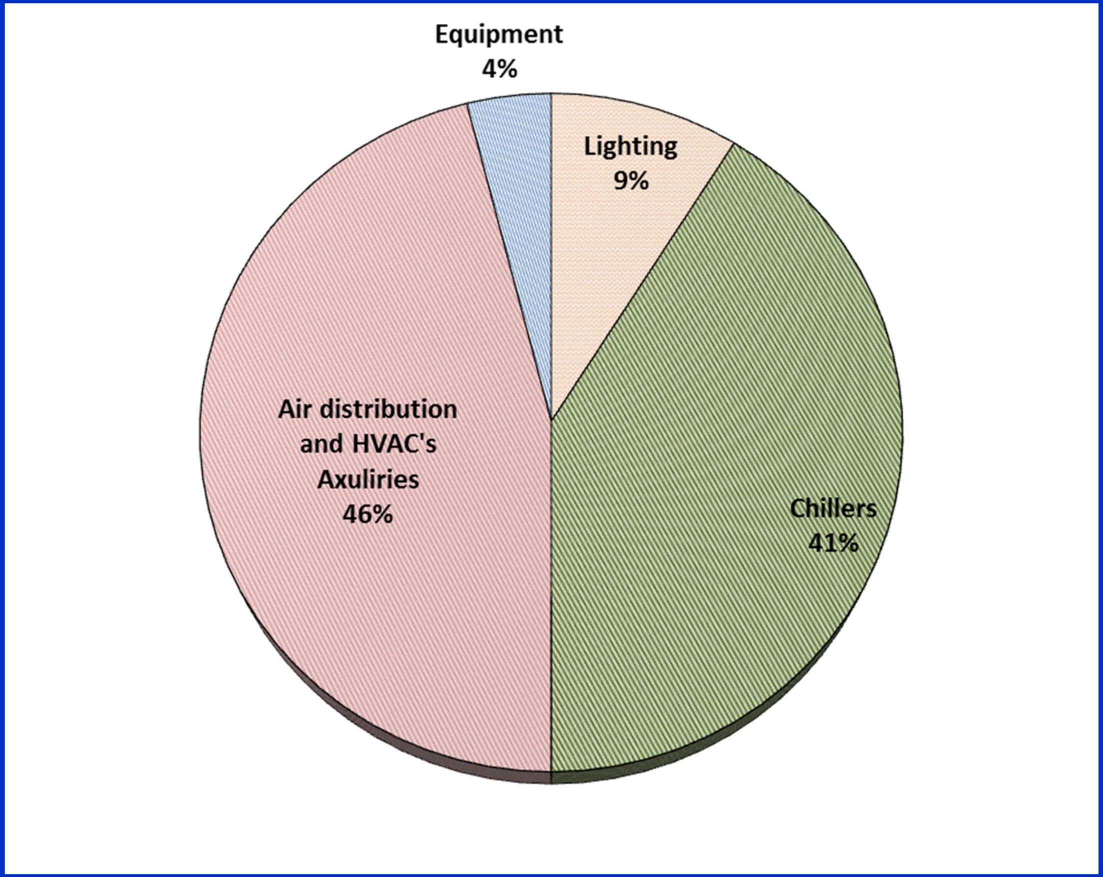
Energy Conservation with Minimum Cost

Table 1: Energy conservation with minimum cost

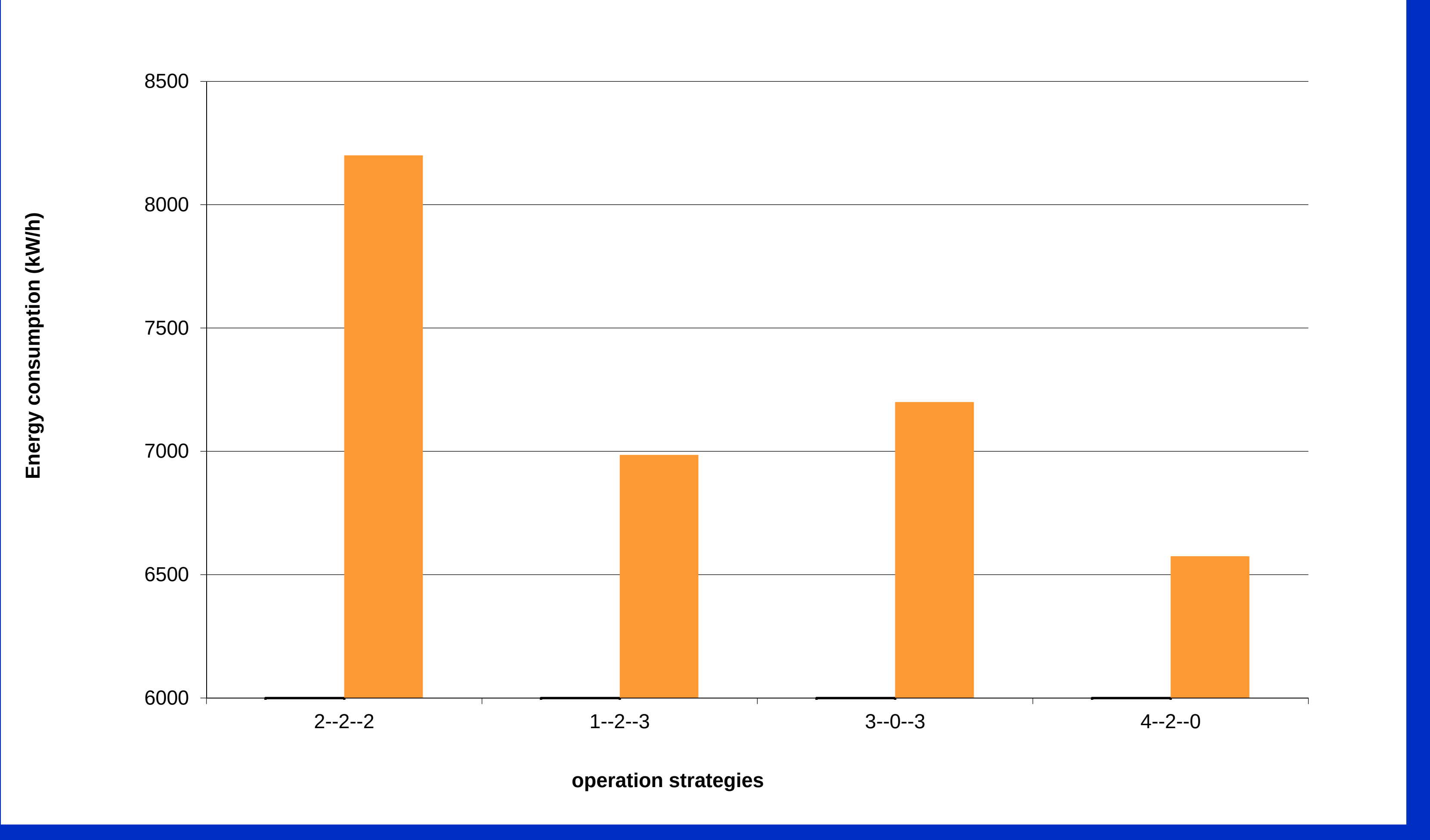
(% energy savings are based on the average building consumption of 4.44 GWh).

No.	***Recommended Actions***	***Energy saving GWh/year***	***% energy saving***
1	*Schedule lighting operation*	*0.10*	*2.3*
2	*Schedule office equipment*	*0.01*	*0.2*
3	*Reduce infiltration*	*0.18*	*4. 1*
	Total	***0.29***	***6.5***

Building Energy Consumption



Average energy consumption during full day for the different operation scenarios



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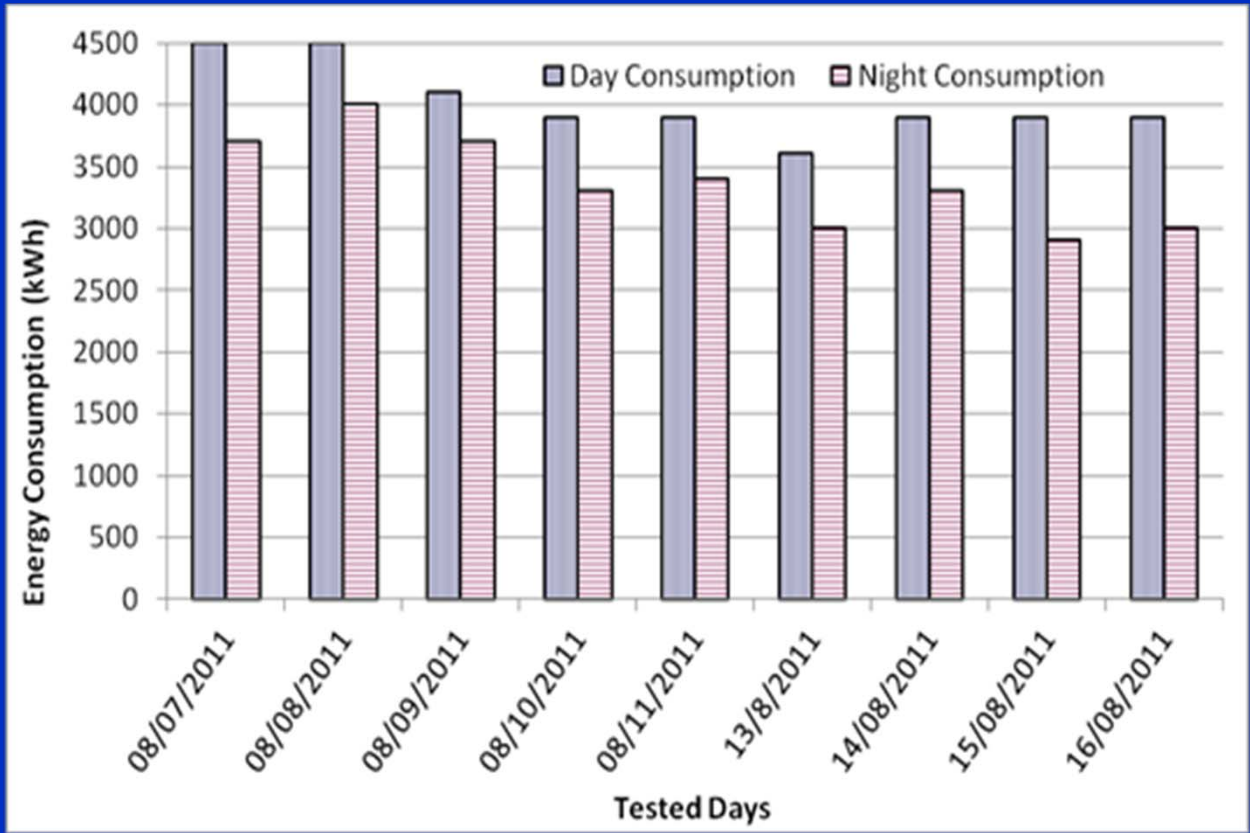
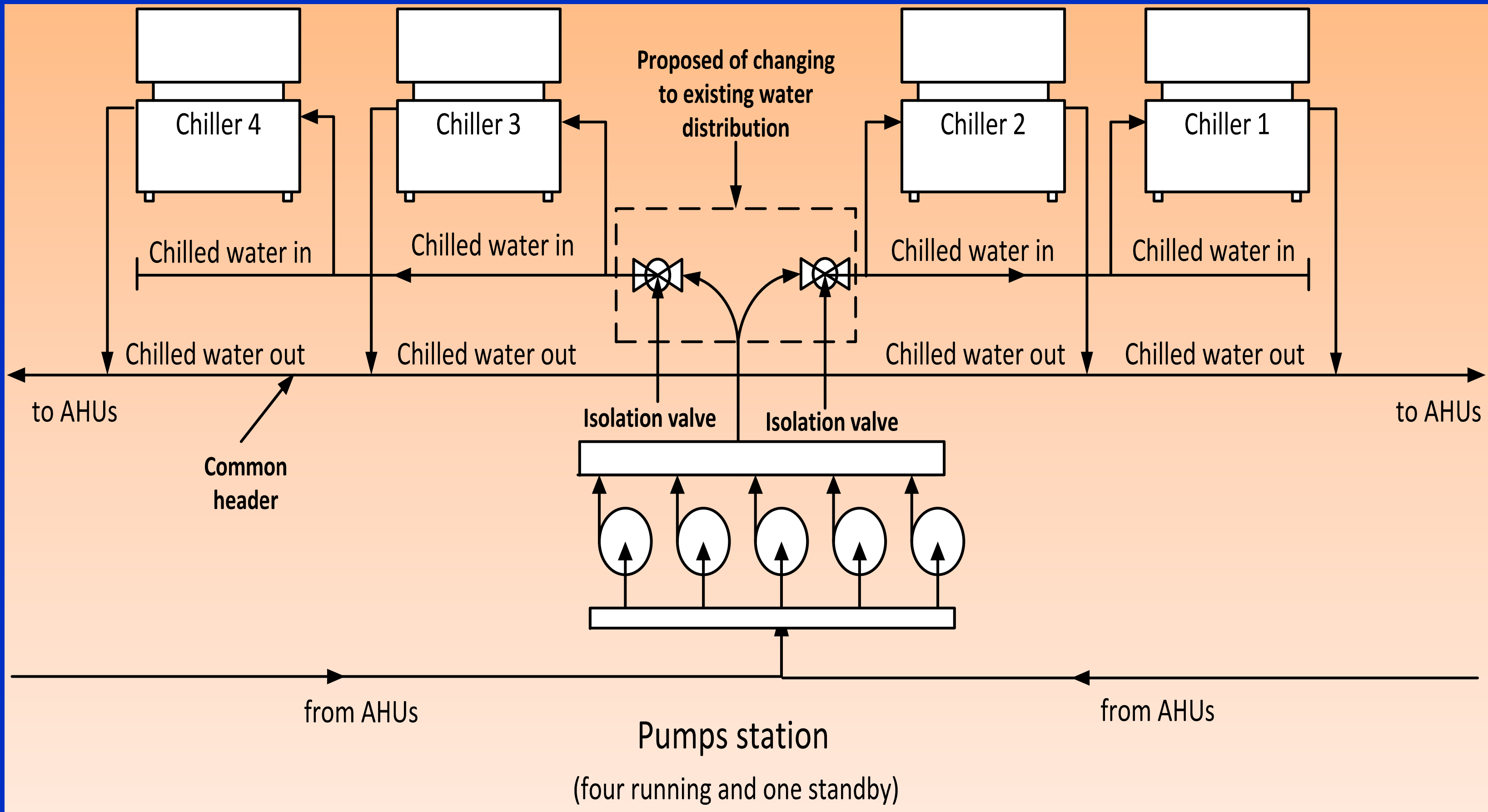
Energy consumption during day time and night time for chilled water plant



Proposed water distribution system for chilled water plant



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Additional Energy Conservation with Minimum Cost

Table 3: Summary of chiller energy saving for different proposed strategies
(% energy savings are based on the chiller consumption of 1900 MWh).

Chillers Operation	***Energy Saving MWh/year***	***% Energy Saving***
Select the best operation scenario	*84.5*	*4.5*
Switch off chillers during non-occupied period (overnight)	*250.1*	*13.2*
Reduce chillers capacity by half during vacation	*53.7*	*2.8*
Reduce pumps capacity by half	*19.8*	*1.0*
Total (% energy savings with respect to chiller consumption)	***408.1***	***21.5***
Total (% energy savings with respect to building consumption)	***408.1***	***9.2***

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Phase-II: Energy Conservation with Investment

Monitoring and Analysis of the Building Performance

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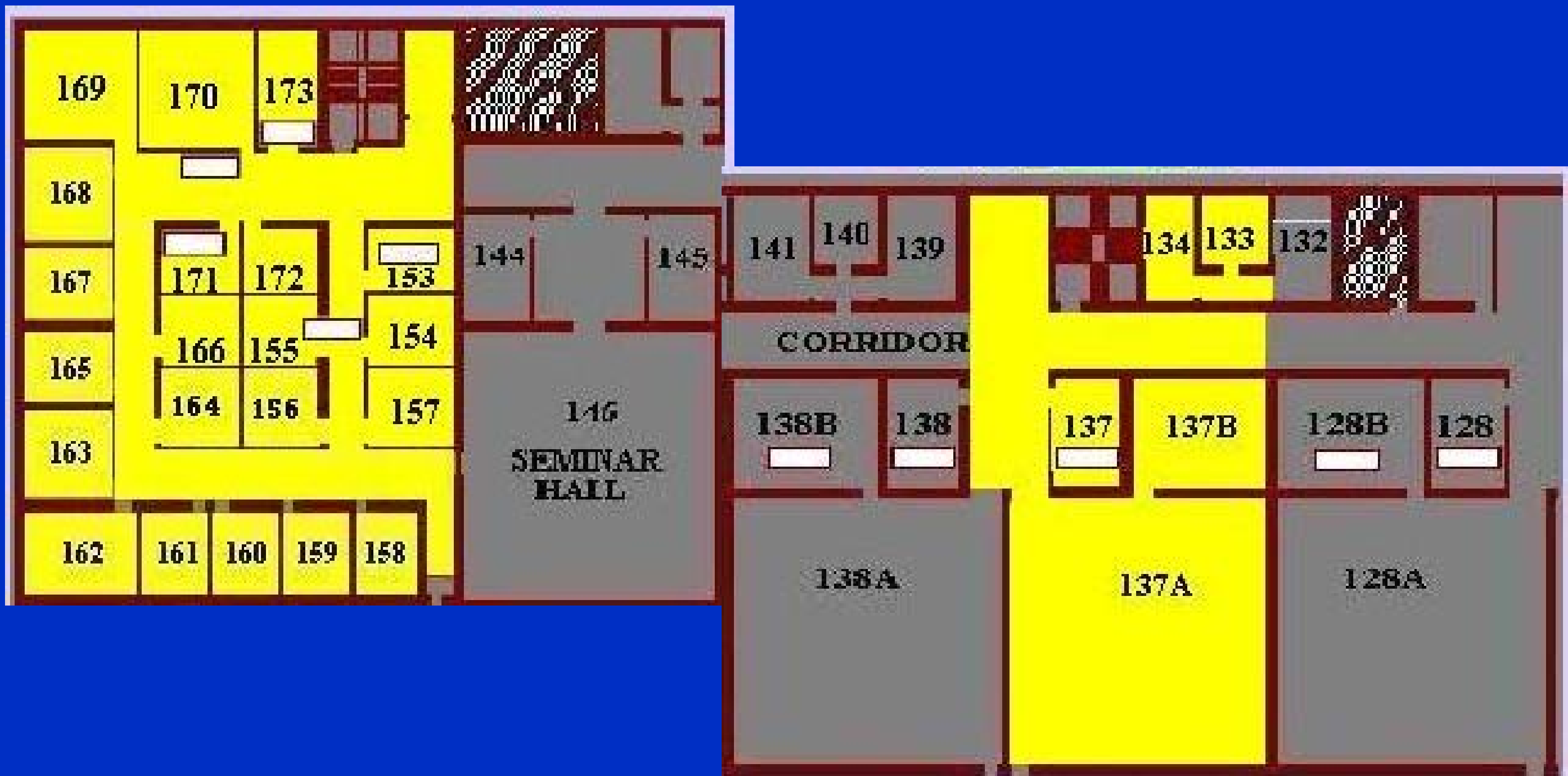
Phase-II: Energy Conservation with Investment

Mini-Data loggers Locations



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Phase-II: Energy Conservation with Investment

AHU Variables Measurements

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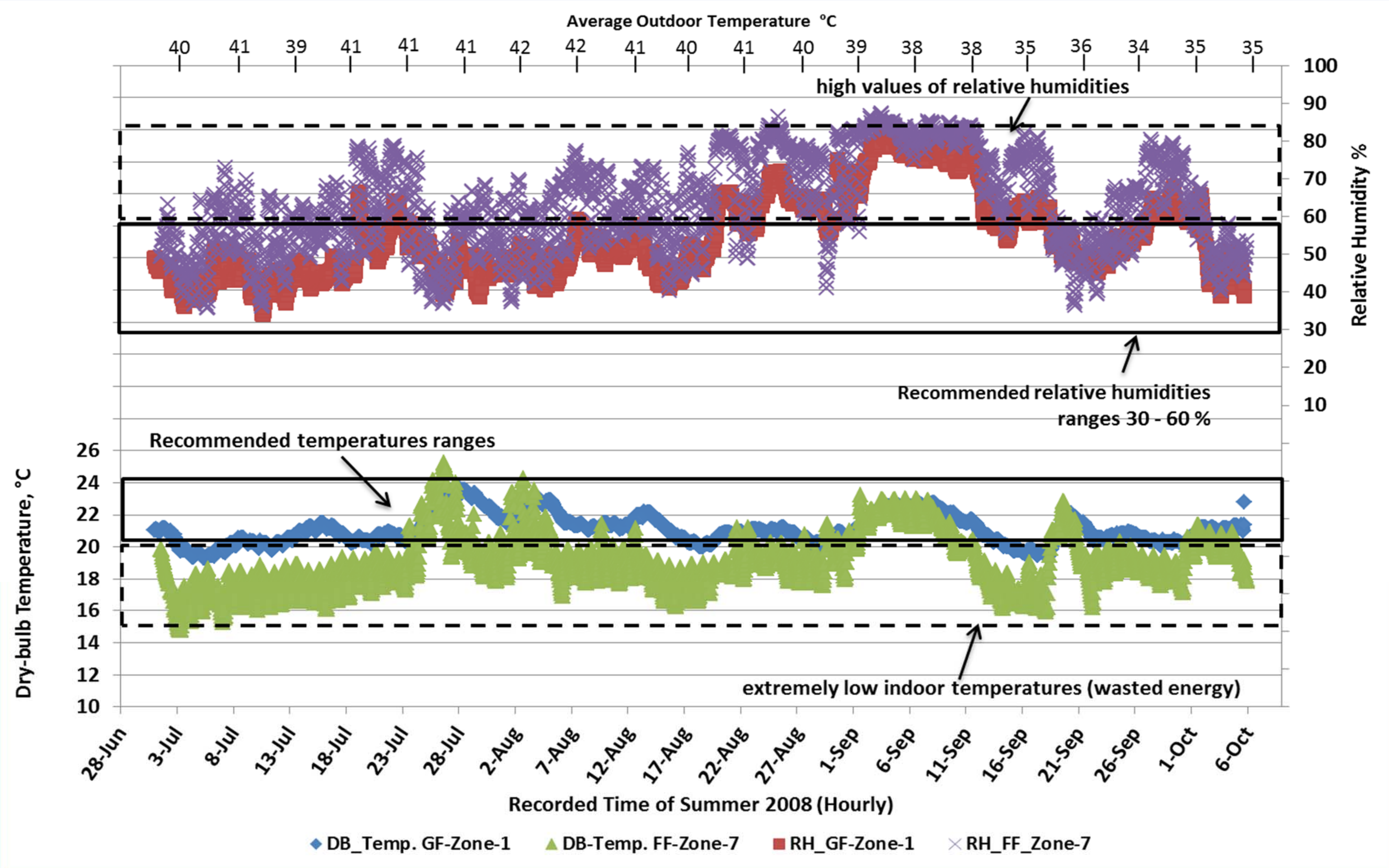
Data Analysis



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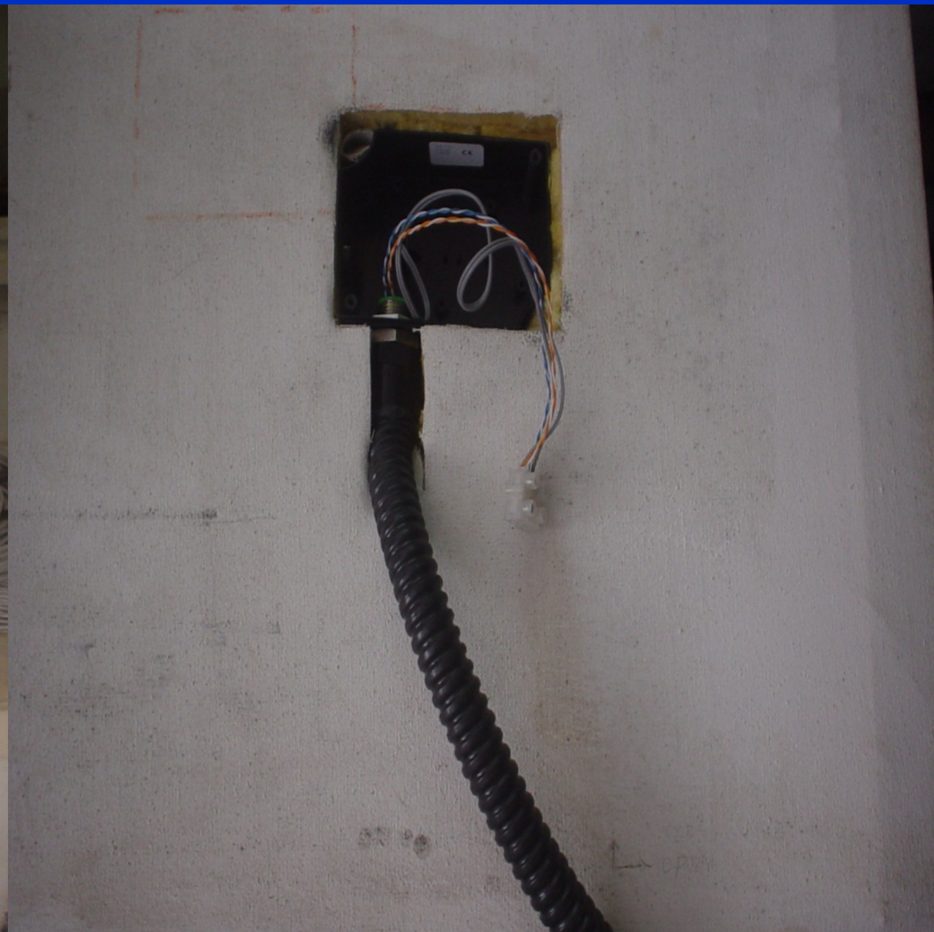
Installation of BMS

Upgrade the HVAC System Control

Installation of BMS



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Installation of BMS

Energy Conservation with Investment

Table 2: Energy conservation with investment.
(% energy savings are based on the average building consumption of 4.44 GWh).

No.	Recommendations	Energy saving GWh/ year	% energy saving
1	Control Indoor Temperature to 24 ºC	1.040	23.4
2	Set-back Temperature to 28 ºC	0.250	5.6
3	Turn off HVAC during weekends	0.590	13. 3
4	Proper maintenance and operation	0.056	1. 3
5	Efficient lighting (T5)	0.100	2. 3
6	Increase roof insulation	0.014	0.3
	Total	**2.050**	**46.2**

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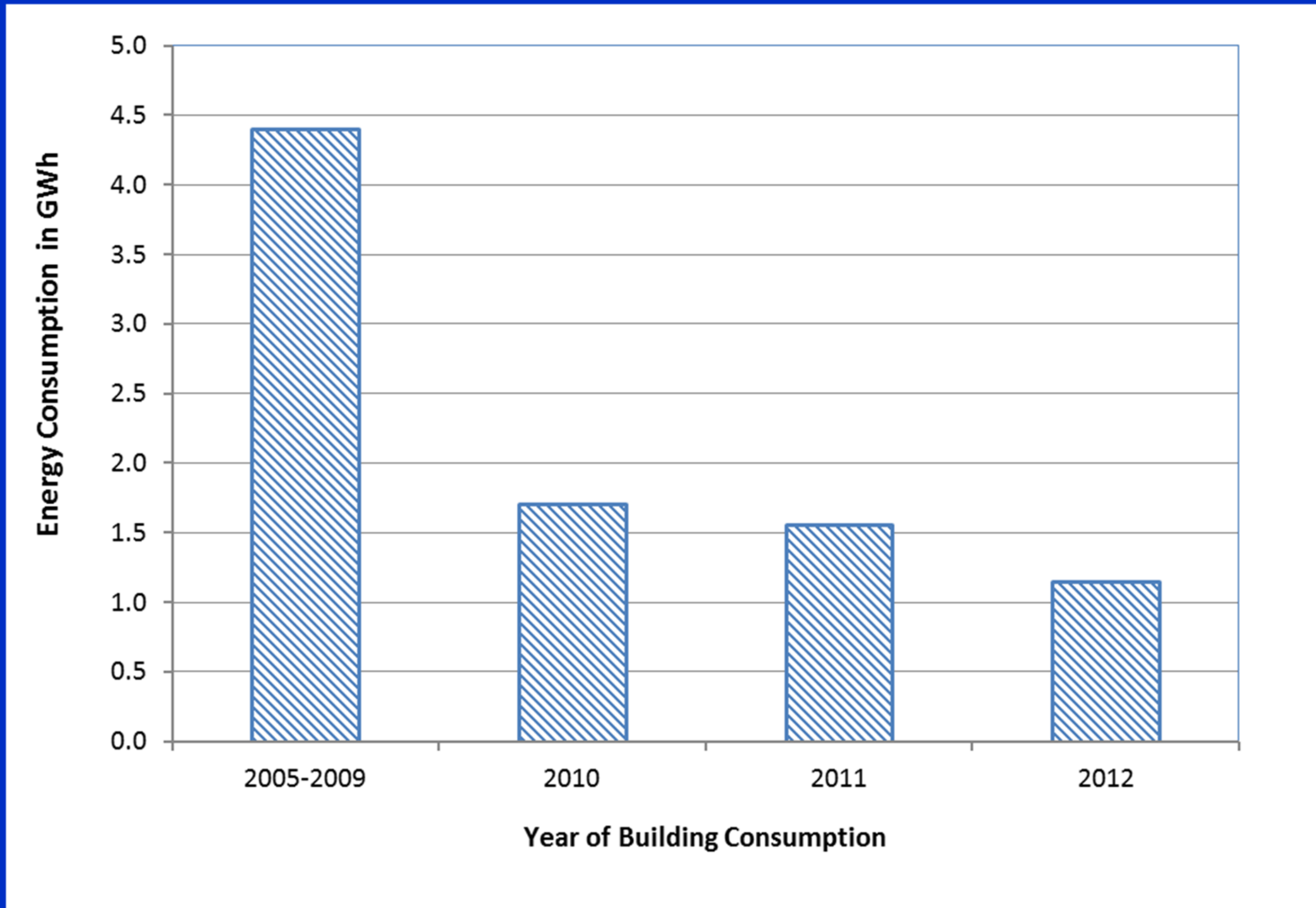
Phase I&II Energy Consumption Reduction



Phase I&II Cost Analysis

		Savings Analysis		
		Annual cost savings (USD/yr)¹	Cost of energy audit team or retrofit (USD)	Simple payback period (yr)
energy reduction in phase-I	Lighting schedule	13,408		
	Equipment schedule	1,190	18311	0.5
	Reduce infiltration (close doors)	23,490		
energy reduction in phase-II	Control indoor temperature	136,886		
	Temperature setback to 28 °C	33,660	109,869	0.5
	Turn off HVAC during weekends	78,509		
	Select the best operation scenario Switch off chillers during non-occupied period (overnight) Reduce chillers capacity by half during vacation Reduce pumps capacity by half	4,896	5,250	1.1
	Efficient lightings (T5)	13,558	16,261	1.2
	Increase roof insulation by 2.5 cm	1,680	7,325	4.4
	HVAC maintenance	7,336	10,071	1.4

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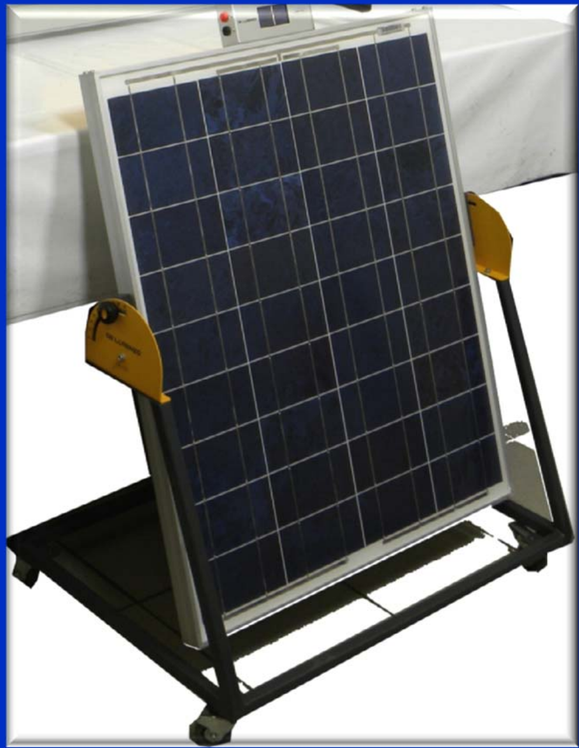
Phase-III: Building Integrated Photovoltaic

- Study the feasibility of using any of the renewable source of energy
- Analyze the building energy consumption profile
- Select the appropriate renewable type and capacity.



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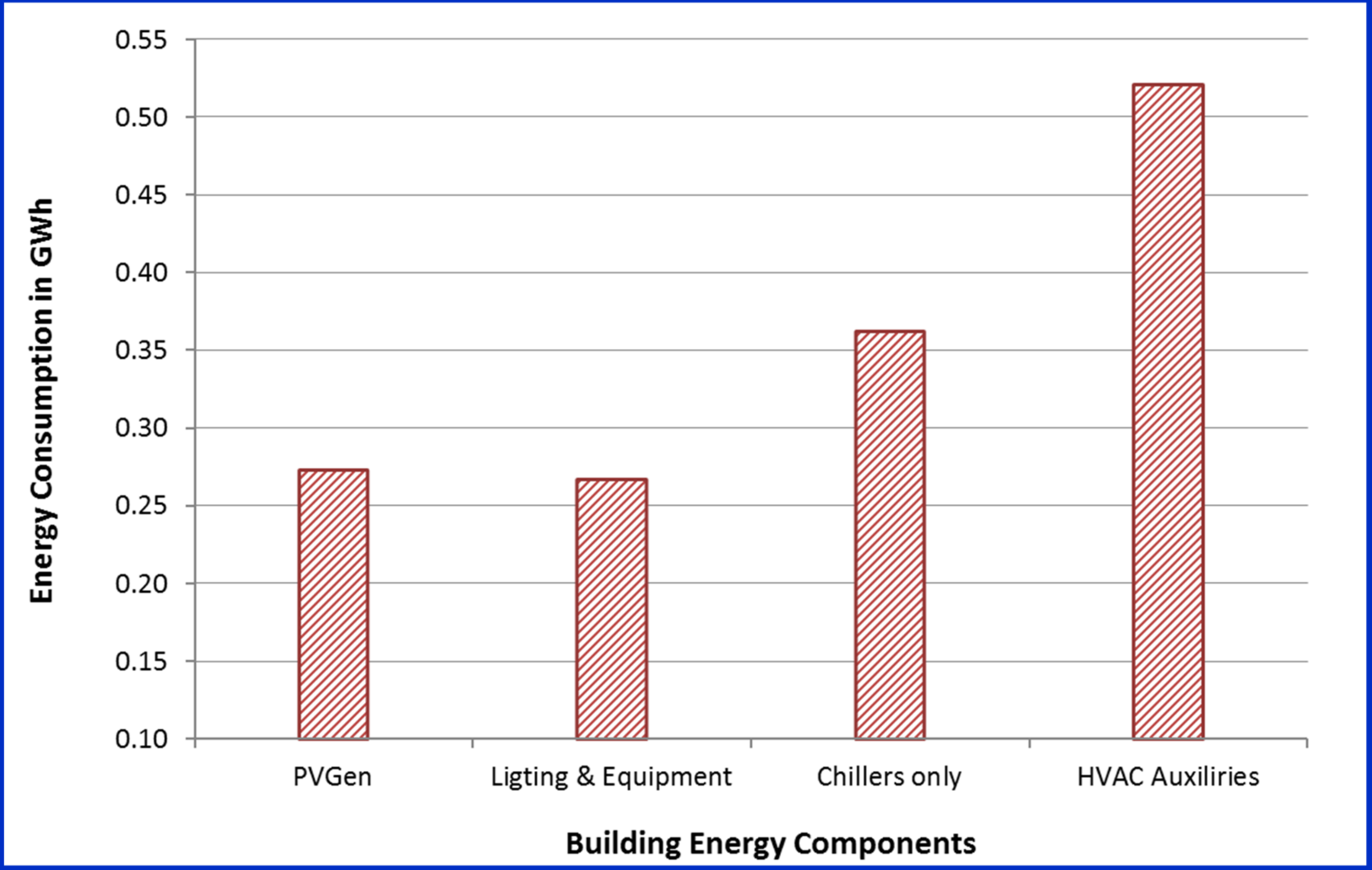
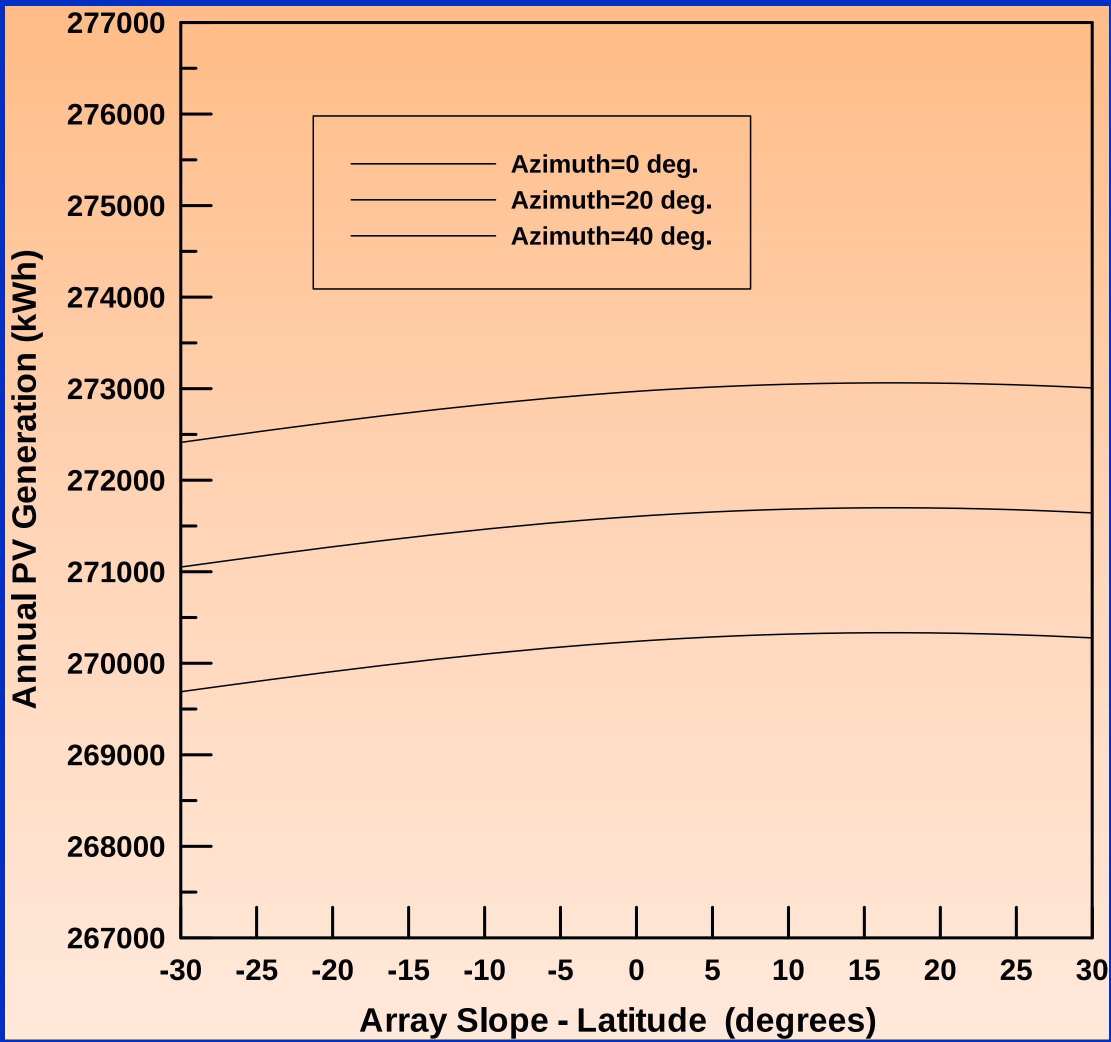
Integrating PV on Existing Building

- Analyze the different sections of energy consumption.
- A Simulation program (DesignBuilder) has been used to predicted the hourly energy consumption.

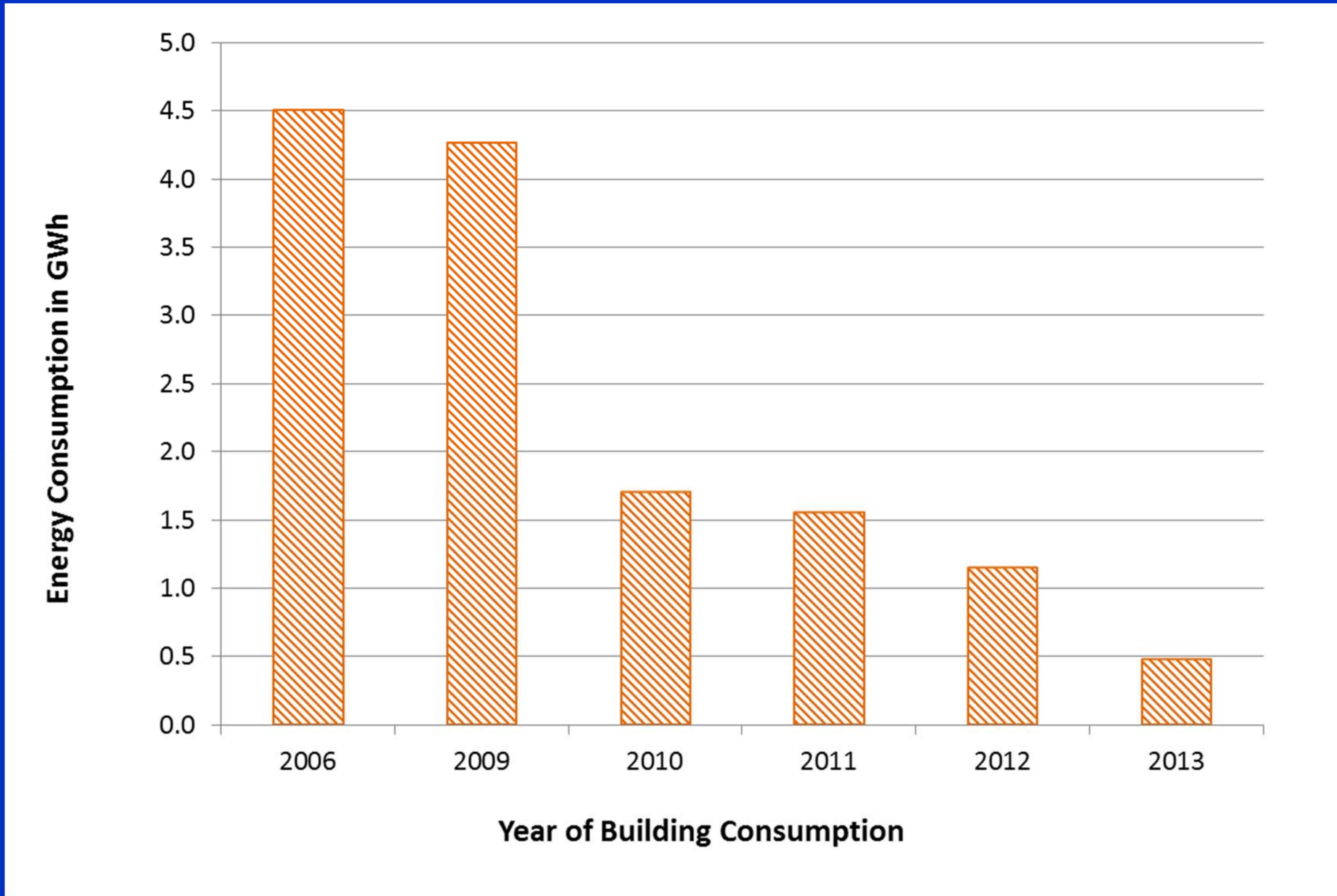
A Yearly Load Profile



PV Annual Energy Generation



Building with the Integrated PV



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Concluding Remarks

- Implementation of phases I & II' recommendations yields reduction of annual consumption from 4.44 GWh to about 1.56 GWh in 2011 as recorded by the building meter.
- The EUI reduces from about 632 to 222 KWh/m^2 compared to:
  - ✓ 171 KWh/m^2; EIA 2003, and
  - ✓ local practical limits (315 to 410 KWh/m^2).
- Retrofitting the lighting system and operation strategies will save about 0.508 GWh which reduces the annual energy consumption to about 1.052 GWh (equivalent EUI of about 150 KWh/m^2).

Concluding Remarks … cont.

- Replacing the existing reciprocating chillers will save more than half the current chillers consumption, i.e. 0.160 GWh.
- Improving the HVAC auxiliaries may lead to a considerable energy saving of about 0.1 GWh.
- The above items will lower the annual consumption to only 0.792 GWh.

Concluding Remarks … cont.

- Integration of the PV modules in buildings results in annual energy generation of about 0.273 GWh.
- This left an annual energy required of about 0.519 GWh which should be supplied using conventional sources.
- The ongoing research on solar cells claims fast developing with respect to higher efficiency and lower cost. Nowadays, the laboratory scale solar cells reach efficiency up to 40% (Atwater, 2008).

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Concluding Remarks … cont.

- Alternatively, with the current used PV efficiency, the area required to balance the power should be increased.
- In conclusion, the forgoing discussion indicates that the mid-size existing buildings can be converted into NZEBs or nNZEB and the decision may depend on the investment required for the conversion.
- Preliminary energy audit of the building results in an annual energy saving of about 290 MWh which is equivalent to 6.5% of the annual consumption.

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Conclusion

- Detailed energy conservation with reasonable investments yields an annual energy savings of about 2.458 GWh which is equivalent to about 55.4% of the annual building consumption
- Efficient operation strategies can reduce the energy consumption of the chillers by about 21.5% which is equivalent to 9.2% of the building energy consumption.
- Efficient energy conservation saves annual energy consumption of the building that is twelve times the energy generated by the PV modules

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Conclusion

- The performance of BIPV systems is greatly influenced by the variation in both array slope and azimuth angle
- The integration of PV modules into the building produces about 27% of the building energy consumption and can cover the lighting and equipment load in the building
- The optimum BIPV can avoid CO_2 emission of about 160 tone/year

Conclusion

- Costs and efficiency of PV modules change dramatically and this will make BIPV systems cost-effective in the near future.
- Nearly NZEB can be achieved in existing buildings
- The results of the present work should encourage governments for wide installation of solar energy systems to keep our environment healthy and clean.

Thanks

LINK