SAARC Energy Centre, Islamabad

Pakistan

THE REPORT

Webinar On "Sensor and Control Technologies in Building"

21st July, 2020

Organized by

SAARC Energy Centre Islamabad

July 21, 2020

SAARC Energy Centre
697, Street 43, Sector E-11/4 (NPF),
Islamabad, Pakistan
www.saarcenergy.org

Introduction

1. SAARC Energy Centre (SEC), Islamabad conducted a webinar on "Sensor and Control Technologies in Buildings" The webinar was held on Tuesday, 21st July 2020. Webinar Agenda is available at Annexure -I.

2. Focus of the webinar was to share the information on how sensor and control technologies can be effectively used for efficient use of energy in the buildings. The aim/motive was to sensitize the policy/decision makers, investors and project developers on such technologies and its benefits. Two presentations were made on "Sensing and Control for Grid-Interactive Efficient Buildings" and "Sensor based Building Energy Efficiency Assessment through Living Lab Concept".

3. The webinar was attended by 33 professionals representing public sector organizations, academia, private sector, and other stakeholders within and outside SAARC region. The experts from Department of Energy, USA and University of Engineering and Technology, Karachi, Pakistan presented technologies of sensor and control which could be used for efficient use of energy in buildings and also shared the details on the projects undertaken in such areas. The participants list is available at Annexure-II.

Description

4. The webinar was started with welcome remarks by Program Coordinator, Mr. Bhaskar Pradhan, Program Leader (Energy Trade) of SAARC Energy Centre. The technical session comprised of presentations by the expert speakers. Each presentation was followed by a brief Q & A session. At the end, the Program Coordinator read out conclusions, which were gathered during the webinar session. Before closing the webinar, the Program Coordinator from SAARC Energy Centre offered remarks of appreciation to all the participants and presenters.

Technical Proceedings

5. In total two resource persons presented and shared their knowledge during the webinar. The first presentation was on “Sensing and Control for Grid-Interactive Efficient Buildings” by Ms. Erika Gupta, Sensor and Controls Technology Manager, office of Energy Efficiency and Renewable Energy, Department of Energy, USA while the second presentation was on “Sensor based Building Energy Efficiency Assessment through Living Lab Concept” by Dr. Farrukh Arif, Associate Professor, Department of Civil engineering, NED University of Engineering and Technology, Karachi, Pakistan.

6. All the presentations delivered during the webinar are available at SEC’s website https://www.saarcenergy.org/webinar-on-use-of-sensor-and-control-technologies-in-buildings/. Details of Resource Persons are available at Annexure-III and their Presentations at Annexure-IV. A brief information on the content of the delivered presentations is as follows:

Ms. Erika Gupta	Sensor and Controls Technology Manager	Department of Energy, USA
Dr. Farrukh Arif	Associate Professor, Department of Civil Engineering, Director	NED University of Engineering and Technology, Karachi, Pakistan

Presentation 1 – “Sensing and Control for Grid-Interactive Efficient Buildings”

Ms. Erika Gupta, Sensor and Controls Technology Manager, Energy Efficiency and Renewable Energy, Department of Energy, USA.

7. Ms. Erika Gupta, is a Sensors and Controls Technology Manager, working with Office of the Energy Efficiency and Renewable Energy, Building Technology Office, USA. Her work at BTO leverages her controls background, focusing on building energy management controls and projects supporting controls for grid-integrated efficient buildings. She joined EERE as a technology development manager in the Fuel Cell Technologies Office in 2012, managing projects that could lower the cost of delivery of hydrogen. Prior to joining FCTO she worked in fuel cell industry as lead control system engineer. Ms. Erika also has a background in reliability engineering and predictive failure analysis. She attained her B.S. in mechanical engineering at Boston University and M.S. in Mechanical engineering with a focus on control systems at Worcester Polytechnic Institute.

8. Ms. Erika talked on number of areas covering current status and future prospects in the use of sensor and control technologies in buildings. She highlighted the current state about the large, medium, small commercial buildings and residential buildings. The sensors and controls program has four focus areas namely hardware, software, cybersecurity and semantic interoperability. She talked about the areas of R&D for hardware and software. On Cybersecurity, she explained that buildings can be remotely accessed by unauthorized agencies so insisted that the cybersecurity capabilities should not be compromised. Under

the semantic interoperability, individual or different building sectors operated uncoordinated when it comes to lighting, commercial and residential load, PV, EV Charging etc. There are no proper standards as such this need clarity becomes costlier, difficult for capacity building, slow services and suppression of competitions. She insisted that such interoperability has to be harmonized, develop semantic data model, engage stakeholders to promote semantic data modelling etc. Further to this, a case study of a Smart Neighbourhoods where 62 homes equipped with relevant technologies were discussed.

Presentation 2 – "Sensor based Building Energy Efficiency Assessment through Living Lab Concept"

Dr. Farrukh Arif, Associate Professor, Department of Civil engineering, NED University of Engineering and Technology, Karachi, Pakistan

9. Dr. Farrukh Arif, Associate Professor, is an educationist and a researcher working at Department of Civil engineering, NED University of Engineering and Technology, Karachi, Pakistan. Dr. Farrukh's areas of research interests include; automation, infrastructure management, virtual reality, building information modelling, intelligent transportation systems etc. Dr. has forty-six publications and he has also been honoured with several awards, including; Chairman Institution of Engineers Pakistan (IEP) medal for best paper, Best University Teacher Award by Higher Education Commission of Pakistan, Outstanding Doctoral Research Award by Florida International University, Graduate Student of the year Award by ASCE Miami.

10. Dr. Farrukh talked on number of topics related to use of sensor in buildings. He highlighted building energy efficiency, energy efficiency assessment, energy efficient simulation, energy audit, living lab concept and setup, sensor-based assessment, sensors' live dashboard, energy efficiency assessment integrated framework etc. He explained that 40% of the global energy use is attributed to the building and energy saving potential for residential and commercial building could be upto 30%. He also talked about the energy audit which helps to diagnose and analyse the energy consumption in buildings. Finally, he explained the concept of Living Lab Setup to know the real time information about the use of energy in buildings and how can it be best monitored and controlled.

Wrap up and Conclusion

Mr. Bhaskar Pradhan, Program Leader (Energy Trade), SAARC Energy Centre

11. Mr. Bhaskar Pradhan thanked everyone for attending the event. He informed the participants that it was very important for SAARC countries to understand the need for efficient use of the energy resources available in South Asian countries. Following are the main conclusions:

a. Use of sensor and control technologies in buildings have multiple benefits. Some of them are listed below:

i. Flexibility in energy use and grid operation
ii. Efficient, Smart and Flexible
iii. Energy Affordability
iv. Improved reliability & resiliency
v. Grid integration and reduction of grid congestion
vi. Enhanced services
vii. Environmental benefits
viii. Customer choice
ix. Identify where most of the energy is being consumed
x. Energy Audit to diagnose and analyze the energy consumption pattern

b. It is important that all SAARC Member States take timely actions towards the energy efficiency measures. One of such measures is the use of technologies to save energy use in buildings. SAARC Energy Centre has always played its role to facilitate and encourage South Asian countries on energy initiatives and will continue to do so by arranging events to allow deliberation on crucial aspects for the benefit of the region.

Closing of Webinar

Mr. Bhaskar Pradhan, Program Leader (Energy Trade), SAARC Energy Centre

12. Mr. Bhaskar Pradhan, informed all the participants that the presentations and recording of the webinar proceedings will be available on SAARC Energy Centre's website (www.saarcenergy.org). He requested the participants to submit suggestions/comments for any further improvement of these webinars and suggest topics that they would like SEC to conduct webinar on. He closed the webinar with a thank you note to everyone attending the Webinar.

Annexures

Webinar on
"Use of Sensor and Control Technologies in Building"
Tuesday, 21st July 2020

1500-1510	Introduction	
1510-1540	"Sensing and Control for Grid-Interactive Efficient Buildings" (**Ms. Erika Gupta**, Sensors and Controls Technology Manager, Office of the Energy Efficiency and Renewable Energy, Building Technology Office, USA)	
	Q&A	
1540-1610	"Sensor based Building Energy Efficiency Assessment through Living Lab Concept" (**Dr. Farrukh Arif,** Associate Professor, Ph.D., Department of Civil Engineering, NED University of Engineering & Technology, Karachi, Pakistan)	
	Q&A	
1610-1620	Conclusions and Recommendations	
1620-1630	Closing of Webinar	

Information for the participants:

1. All times mentioned in agenda are according to Pakistan Standard Time (PKT). The participants from other Member States may attend Webinar by following their own national time. The time conversion for all Member States is given below for reference:

Country	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Sri Lanka
Local time	(PKT-00:30)	(PKT+01:00)	(PKT+01:00)	(PKT+00:30)	PKT	(PKT+00:45)	(PKT+00:30)

2. The participants can ask questions to presenters by typing questions or clicking to the Raised Hand option into the Attendees Pane of the main window of GotoWebinar software. You may send in your questions at any time during the presentations; we will collect these and address them during the Q&A session at the end of each presentation.
3. All participants can also submit comments/views and/or observations on this webinar to SAARC Energy Centre through email to Mr. Bhaskar Pradhan, Program Leader (Energy Trade) (plet@saarcenergy.org) before 28th July, 2020.

List of Participants

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33.	Karma	Karma	karmalob@gmail.com

List of Presenters/Resource Persons

Sr. No.	Name	Designation	Organization	Email address
1.	Ms. Erika	Gupta	Office of the Energy Efficiency and Renewable Energy, Building Technology Office, USA	erika.gupta@ee.doe.gov
2.	Dr. Farrukh	Arif	University of Engineering & Technology, Karachi, Pakistan	farrukharif@gmail.com

Presentations Delivered During the Webinar

1. "Sensing and Control for Grid-Interactive Efficient Buildings" by Ms. Erika Gupta.

Sensor and Controls Technology Manager, Energy Efficiency and Renewable Energy, USA.

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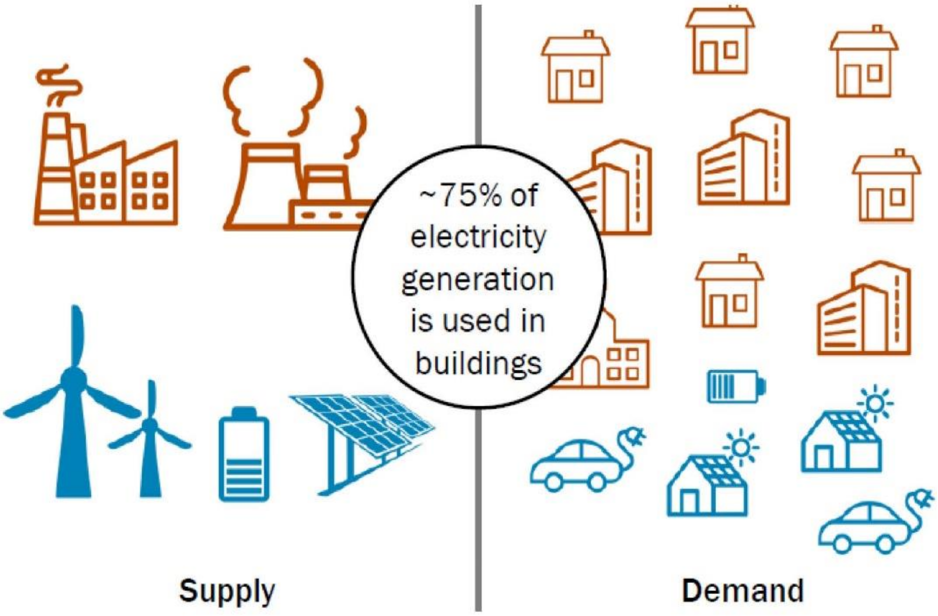
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

GEB and S&C Overview

Building Technologies Office
July 21, 2020

GEB is about enabling buildings to provide flexibility in energy use and grid operation



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Potential Benefits of Flexible Building Loads
✓ Energy Affordability
✓ Improved reliability & resiliency
✓ Reduced grid congestion
✓ Enhanced services
✓ Environmental benefits
✓ Customer choice
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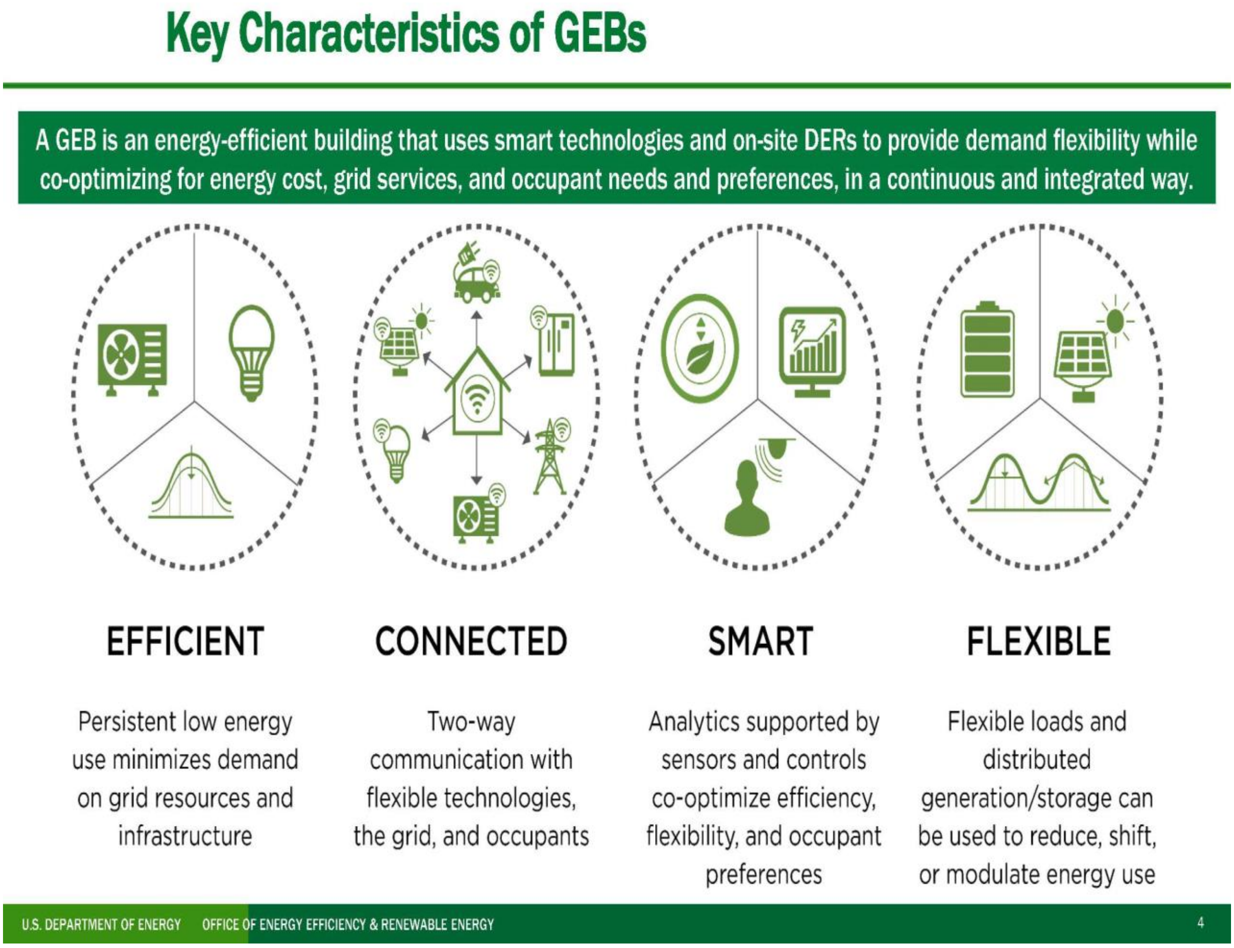
Key Characteristics of GEBs
A GEB is an energy-efficient building that uses smart technologies and on-site DERs to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences, in a continuous and integrated way.
EFFICIENT
Persistent low energy use minimizes demand on grid resources and infrastructure
CONNECTED
Two-way communication with flexible technologies, the grid, and occupants
SMART
Analytics supported by sensors and controls co-optimize efficiency, flexibility, and occupant preferences
FLEXIBLE
Flexible loads and distributed generation/storage can be used to reduce, shift, or modulate energy use
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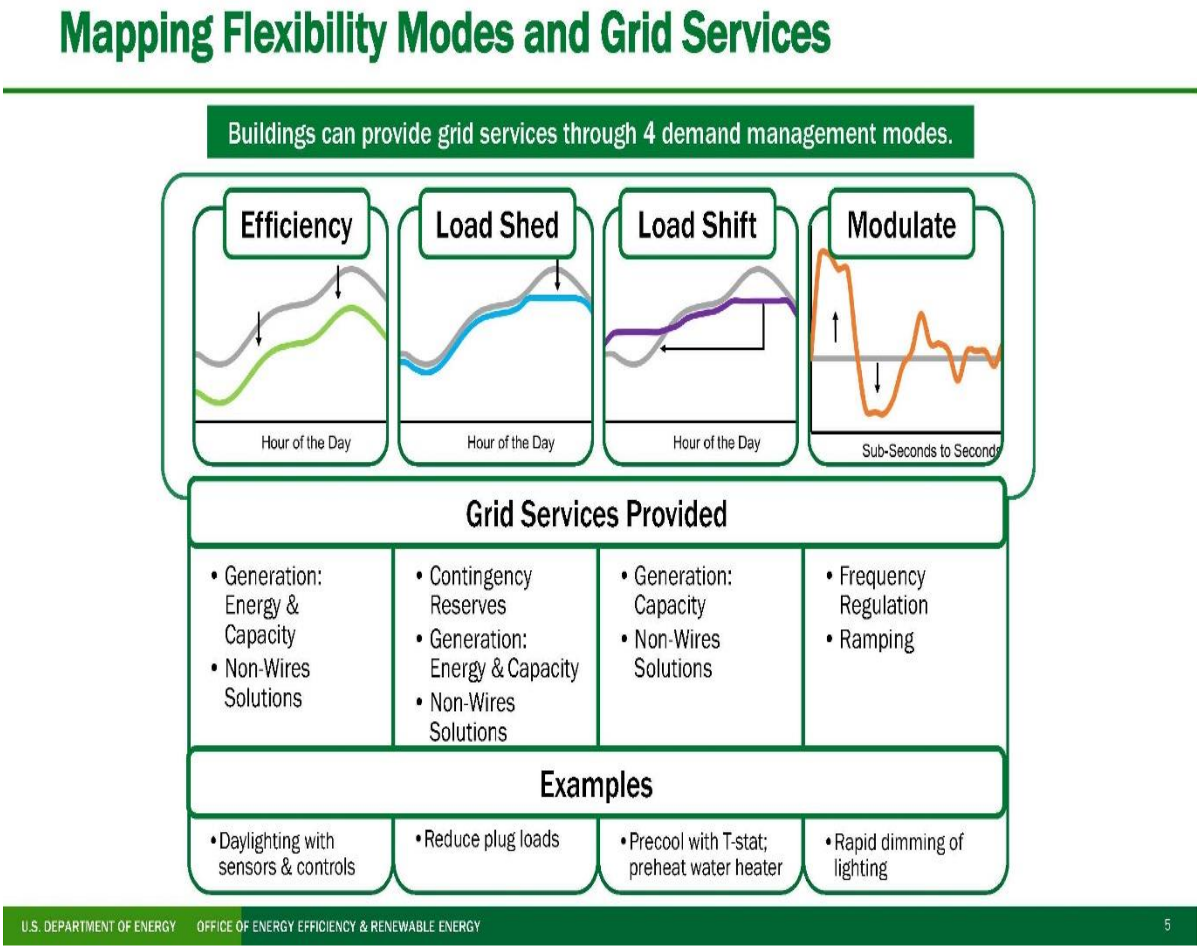
Mapping Flexibility Modes and Grid Services
Buildings can provide grid services through 4 demand management modes.
Efficiency
Hour of the Day
Load Shed
Hour of the Day
Load Shift
Hour of the Day
Modulate
Sub-Seconds to Seconds
Grid Services Provided
• Generation: Energy & Capacity
• Non-Wires Solutions
• Contingency Reserves
• Generation: Energy & Capacity
• Non-Wires Solutions
• Generation: Capacity
• Non-Wires Solutions
• Frequency Regulation
• Ramping
Examples
• Daylighting with sensors & controls
• Reduce plug loads
• Precool with T-stat; preheat water heater
• Rapid dimming of lighting
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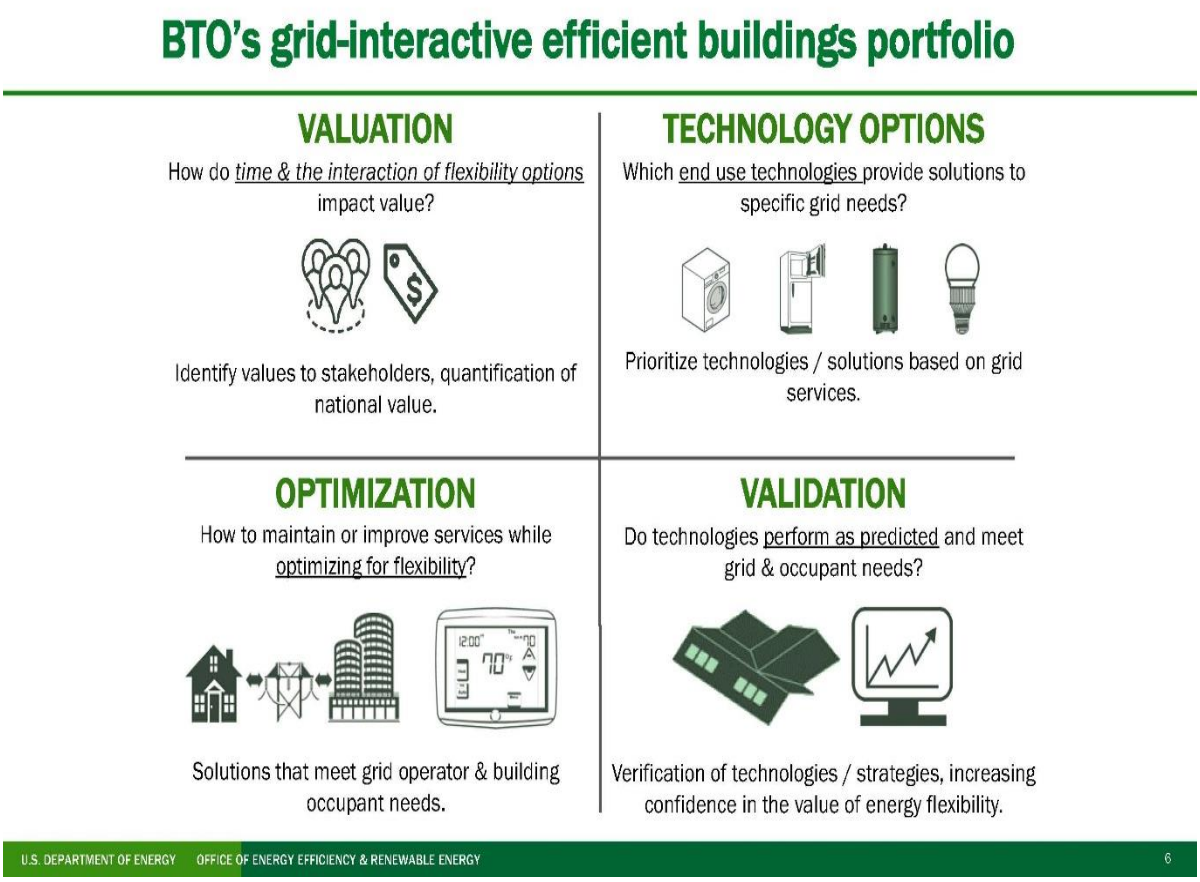
BTO's grid-interactive efficient buildings portfolio
VALUATION
How do time & the interaction of flexibility options impact value?
Identify values to stakeholders, quantification of national value.
TECHNOLOGY OPTIONS
Which end use technologies provide solutions to specific grid needs?
Prioritize technologies / solutions based on grid services.
OPTIMIZATION
How to maintain or improve services while optimizing for flexibility?
Solutions that meet grid operator & building occupant needs.
VALIDATION
Do technologies perform as predicted and meet grid & occupant needs?
Verification of technologies / strategies, increasing confidence in the value of energy flexibility.
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Key Activities 2020-2021

Stakeholder Engagement

- Utility working group focused on EE/DR integration & GEB projects
- State working group focused on 4 TA areas: Potential, pilots, lead by example & valuation
- Commercial building working group focused on technology optimization & business case
- GEB Roadmap focused on a national perspective of defining potential and implementation needs to scale GEBs

Research & Validation

- Demand flexibility technology metrics
- Continued focus on research projects across HVAC, lighting, water heaters, appliances, controls, modeling focused on determining demand flexibility capability (BENEFIT FOA)
- Community focus on demand flexibility (Connected Communities FOA)
- Occupant thresholds and impacts
- Commercial, residential, community DF datasets from validation projects

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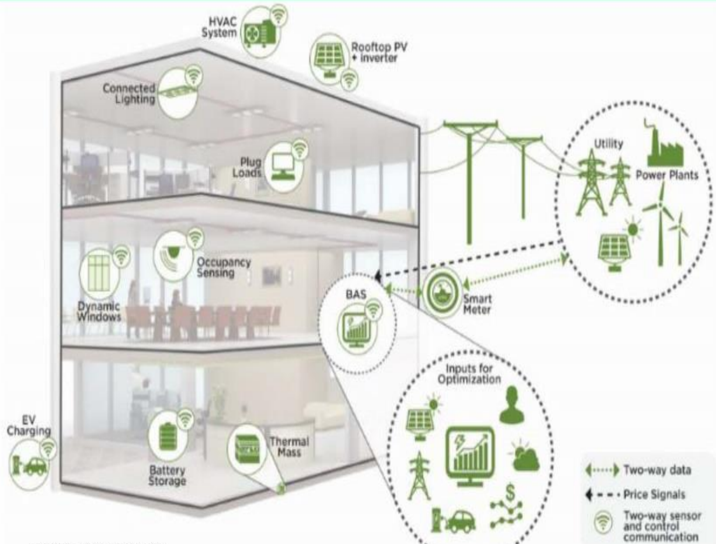
GEB Technical Report Series Overview

The GEB Technical Report Series outlines key demand flexibility opportunities across BTO's R&D portfolio: http://energy.gov/eere/buildings/grid-interactive-efficient-buildings

Technical Report Series:

- Overview of Research Challenges
- Heating, Ventilation, & Air Conditioning (HVAC); Water Heating; and Appliances
- Lighting & Electronics
- Building Envelope & Windows
- Sensors & Controls, Data Analytics, and Modeling



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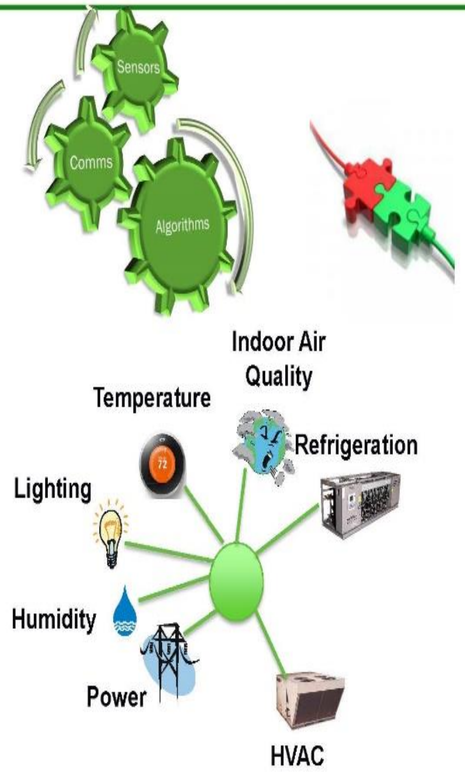
Sensors and Controls: Current State



- Today's stock of buildings are noticeably "unconnected"
  - Limited by existing control and coordination
  - Advanced automation only in large buildings
  - Value streams are often hidden and untapped
- Energy efficiency, grid integration, renewable integration
  - Building equipment integration and grid-interactivity
- Improved integration of BAS and IoT approaches for deploying technology can enable new services
- Retrofit deployment with ROI in 1-2 years

Sensors and Controls: Current State

- Large commercial buildings
  - Most BAS monitor and control HVAC. + Lighting and others for some
  - May include AFDD
  - Rule-based control
- Medium and small commercial buildings
  - Most have packaged units (e.g. RTUs)
  - Low operational and convenience benefits for central control
- Residential buildings
  - Rapid adoption of smart thermostats, voice assistants
  - Could aid in integrated energy management

The Sensors and Controls Program has 4 Focus Areas

1. Hardware
2. Software
3. Cybersecurity
4. Semantic interoperability

1. Hardware – R&D areas

- Develop low-cost sensor technologies
  - Low-cost hardware through innovation in materials and manufacturing methods
  - Cost-effective low-volume sensor production and deployment
  - Multi-modal sensing platforms coupled with energy-harvesting-based approaches minimize operational and maintenance costs for buildings
- Develop sensor technologies with reduced installation and commissioning costs
  - Self-configuration, self-commissioning, and self-optimization
  - Enable sensor networks with little to no engineering effort
  - Automated intelligent re-calibration - reducing maintenance costs
- Investigate the applicability and performance of integrating new sensor technologies into the existing systems
  - Retro-commissioning, evaluating and integrating new sensing technologies with existing systems
  - Reference guidelines for the building/HVAC industry

1. Hardware - R&D areas (Cont'd)

- Develop optimal sensor placement and configuration algorithms
  - Optimal sensor placement algorithms - reduce the number of deployed sensors optimal building operations
  - Reduce cost and effort required to measure and process a large amount of redundant data sources
- Develop advanced actuators
  - Low-cost, low-power, miniaturized (small and lightweight) and durable actuators
  - Minimal re-calibration to enable highly granular building operations
- Design actuators with embedded intelligence
  - Next-generation actuators with embedded intelligence
  - Enable context-aware operation
  - Proactively fault-remediation and avoid performance degradation

2. Software - R&D areas

- Develop the fundamental and practical aspects of model-based predictive control for large and medium commercial buildings.
- Evaluate MPC for residential buildings through field tests.
- Develop methods of prioritizing different zones and end uses within a building and coordinating energy efficiency and grid service delivery across those zones and end uses.
- Develop methods of acquiring occupant comfort states and preferences

2. Software - R&D areas (Cont'd)

- Develop methods of registering occupant prioritization and valuation of different end uses.
- Standardize data pre-processing for data-driven techniques
- Develop the practical aspects of an automated and cost-effective transactive control package for grid services.

3. Cybersecurity – Current Status

- IT vs OT paradigm
- Buildings can be remotely accessed by unauthorized agencies
- No disaster recovery plan
- No changes to default configuration settings
- Cybersecurity capabilities minimizes loss of critical function

3. Cybersecurity – R&D areas

- Develop retrofit solutions
- Develop vulnerability assessments
- Research threat detection algorithms
- Research adaptive and self-healing technologies
- Develop cybersecurity standards
- Leverage existing resources
  - NIST Framework for Improving Critical Infrastructure (NIST-CSF)
  - Building Cybersecurity Framework (BCF)
  - Building Cybersecurity Capability Maturity Model (B-C2M2)

4. Semantic Interoperability – current status

- Each building adjacent industry may have its own model ... or several of them
  - Lighting, packaged commercial HVAC, packaged residential HVAC, PV, EV charging, etc.
- Different building sectors may use different models as well
  - Healthcare, retail, commercial building real-estate, etc.
- Different organizations trying to harmonize different subsets
  - These efforts are themselves uncoordinated
  - https://xkcd.com/927/

4. Semantic Interoperability – current status

- Descriptions of devices, their capabilities, and relationships to each other and building
  - No testable standard for minimal information required to support different applications, e.g., FDD
  - Each EMIS and BAS data model is essentially custom
- Example: Zone1 which is served by VAV4, which itself is served by AHU1
  - Technician #1: { @1: "dis: Z1thermostat" @2: "dis: Z1VAV", @3 "dis: FL1AHU" }
  - Technician #2: { @z1: "dis: Zone1, floor: 1, equipRef: @v1", @t1: "dis: Zone1 Thermostat, zoneRef: @z1", @v1: "dis: VAV4, zoneRef: @z1, equipRef: @a1", @a1: "dis: AHU1" }
  - Both models can be made to "work" individually, but #2 is more "complete" and useful downstream
- Consequences
  - Manual configuration of individual installations is an effort and cost barrier
  - Outside contractors must spend time learning each new building
  - Adoption of new and upgraded services is slow to scale up
  - Competition for services like FDD, ASO, etc. is suppressed

4. Semantic Interoperability – R&D Areas

- Harmonize existing semantic modeling frameworks, fill in as necessary
- Develop minimal requirements for different use cases of semantic data modeling
- Develop semantic data model conformance and completeness testing frameworks
- These support procurement of compliant semantic data model installations
- Develop translation tools to ease transition of existing systems
- Engage stakeholders to promote semantic data modeling

Bringing it all together – Examples of current work

Smart Neighborhoods

- What:
  - Develop, demonstrate, and validate a scalable control framework to co-optimize energy cost, occupant comfort, grid reliability and resilience in next generation neighborhoods that integrate renewable energy sources and energy storage solutions.
  - Field verified in a neighborhood of 62 homes built with the Southern Company.
- Why:
  - Critical need to have access to model homes for testing and validation of the next generation of technologies and control methodologies.
- Results:
  - An open-source framework for deploying grid-interactive controls within residential neighborhoods to improve energy efficiency, reduce energy costs, and improve grid resiliency.
  - Real data collection from occupied homes that will serve as a requirement specification for enabling adoption across other utilities.

Partners

OAK RIDGE National Laboratory

Southern Company

Smart Neighborhoods

- How:
  - The study is being done at a neighborhood of 62 homes equipped with relevant technologies. The homes have energy efficient envelopes, lighting, heat pumps and hybrid heat pump water heaters as specified by Southern Company.
  - ORNL used the open source platform VOLTTRON to develop a transactive control framework to acquire information from the appliances, model the home performance and dispatch the home loads through setpoint and mode adjustments.
  - The objectives of the project include:
    - Quantifying the value of preheating and precooling homes
    - Quantifying the value of operating microgrid Distributed Energy Resources
    - Demonstrate controls algorithms that can keep electricity loads at desired values
    - Evaluate price signal design with a microgrid and controllable loads
    - Develop system-level architecture for transactive control of end-use loads, generation, and storage resources
    - Demonstrate advanced metering algorithms than can disaggregate individual loads

Current Collaboration Example: Behind-the-Meter-Storage (BTMS) Analysis

- What:
  - Develop and analyze new behind-the-meter storage (BTMS) solutions, such as battery systems and thermal storage, to facilitate grid services (electric vehicle charging, solar power generation, demand flexibility, etc.)
- Why:
  - BTMS is needed to mitigate high electric demand charges, to facilitate onsite building renewables and electric vehicle (EV) charging.
  - The synergies of how electrochemical storage (batteries) and thermal storage can work together is an unanswered question.
- Results:
  - Produce behind-the-meter battery solutions that can be deployed at scale and meet the functional requirement of high-power EV charging.
  - Develop and identify the specific functional requirements for BTMS battery solutions that will provide novel battery systems in the 1–10 MWh range at $100/kWh installed cost and able to cycle twice per day, discharging for at least 4 hours, with a lifetime of roughly 20 years or at least 8,000 cycles.

Partners

NREL Transforming ENERGY

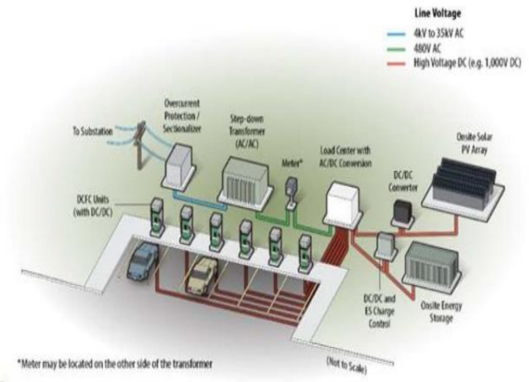
INL Idaho National Laboratory 70 YEARS OF SCIENCE & INNOVATION

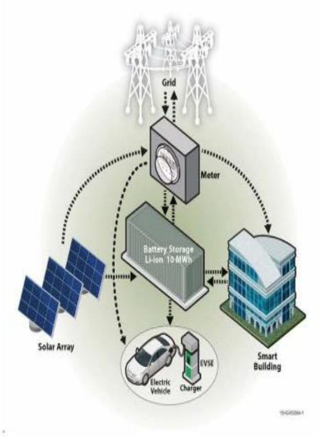
Sandia National Laboratories

OAK RIDGE National Laboratory

Current Collaboration Example: Behind-the-Meter-Storage (BTMS) Analysis

- How:
  - Use modeling and experiments to understand the tradeoffs and synergistic effects of using BTM electrochemical and thermal energy storage, including the development of control strategies.
  - Develop new thermal energy storage characterization methods, both at the materials and device scales.
  - Use building- and system-level modeling to understand the charge/discharge requirements of thermal energy storage for different building applications.
  - Produce critical-material-free battery solutions that meet application specific requirements.

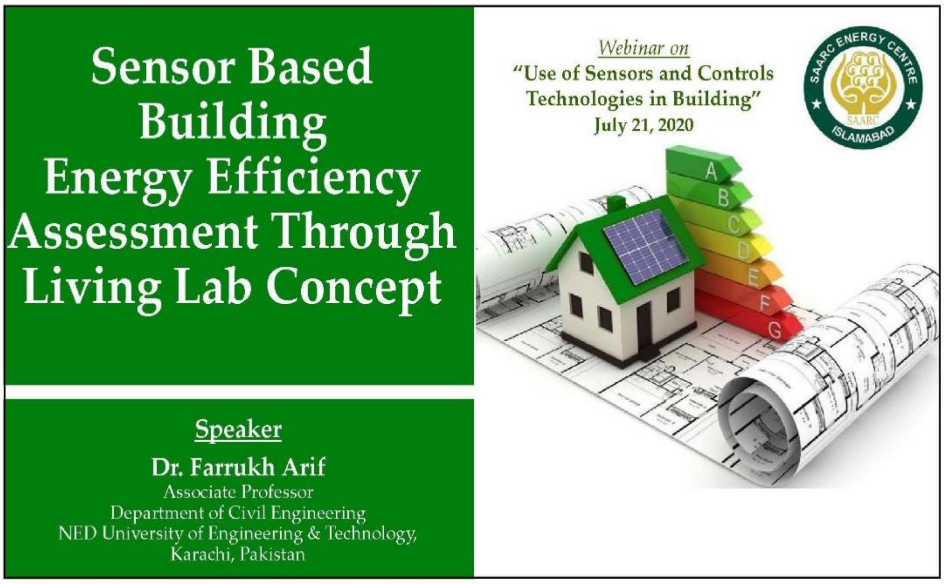


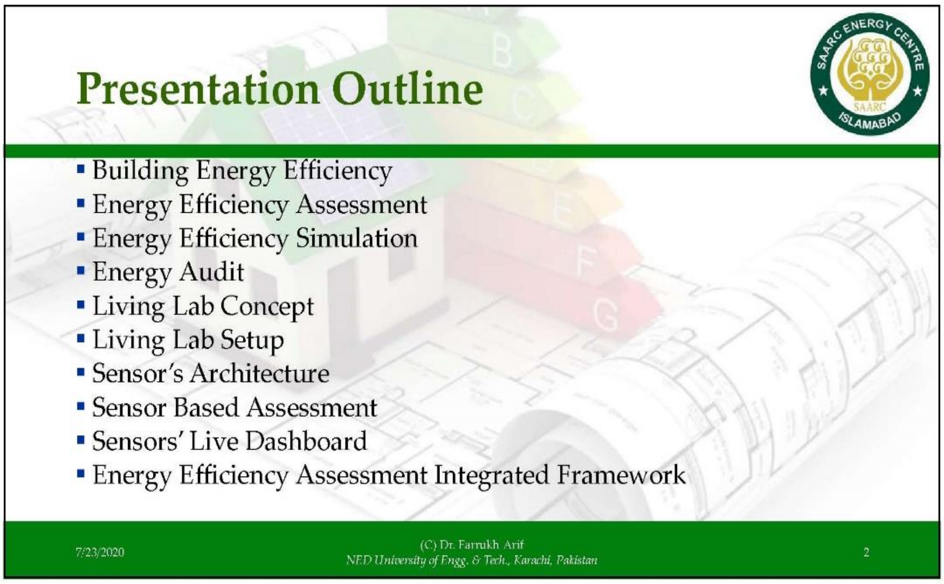


Questions?

2. **“Sensor based Building Energy Efficiency Assessment through Living Lab Concept” by Dr. Farrukh Arif.**
Associate Professor, Department of Civil engineering, NED University of Engineering and Technology, Karachi, Pakistan.

(C) Dr. Farrukh Arif 7/23/2020





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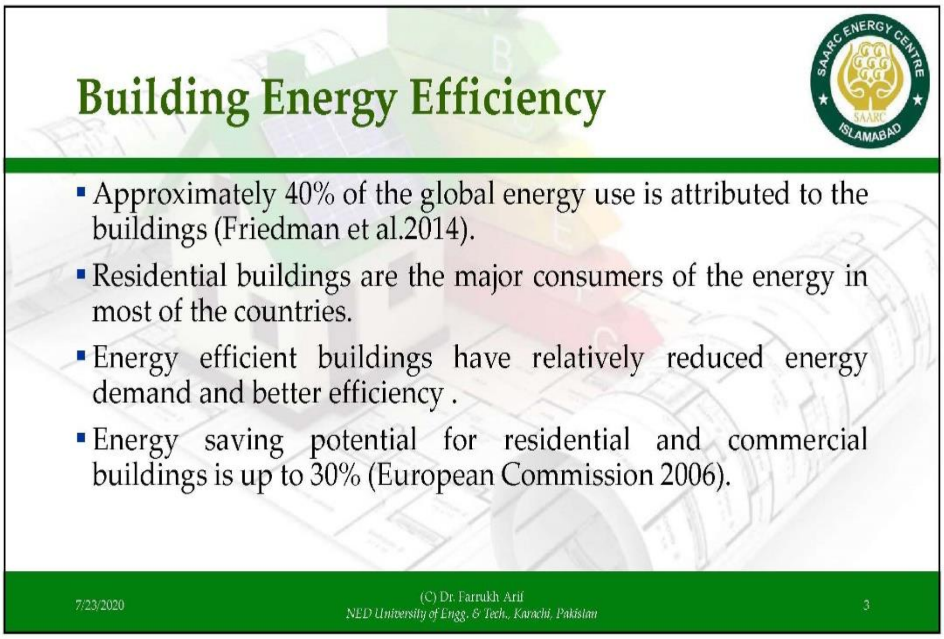
Building Energy Efficiency
SAARC ENERGY CENTRE ISLAMABAD
▪ Approximately 40% of the global energy use is attributed to the buildings (Friedman et al.2014).
▪ Residential buildings are the major consumers of the energy in most of the countries.
▪ Energy efficient buildings have relatively reduced energy demand and better efficiency .
▪ Energy saving potential for residential and commercial buildings is up to 30% (European Commission 2006).
7/23/2020
(C) Dr. Farrukh Arif
NED University of Engg. & Tech., Karachi, Pakistan
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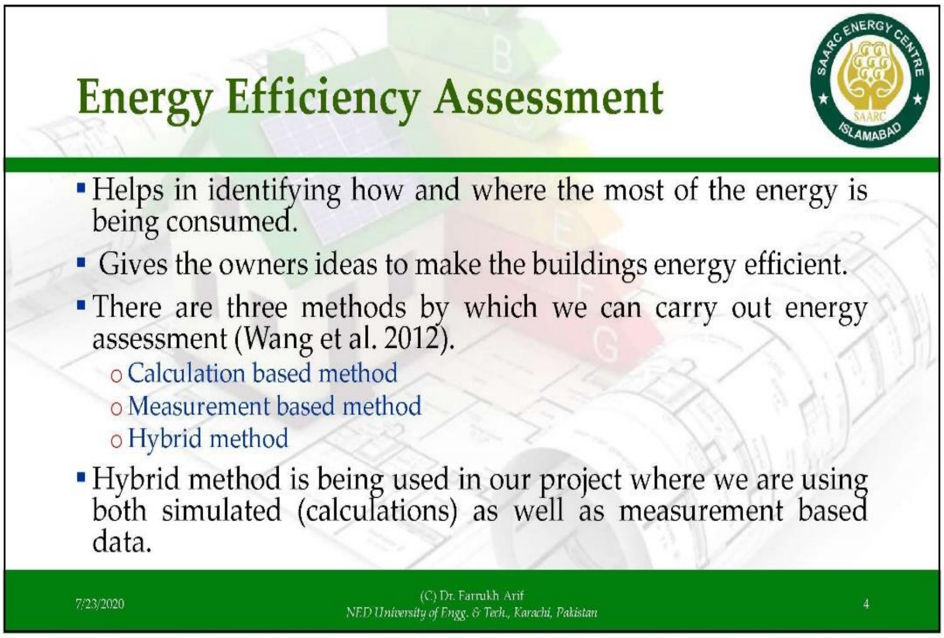
Energy Efficiency Assessment
SAARC ENERGY CENTRE ISLAMABAD
▪ Helps in identifying how and where the most of the energy is being consumed.
▪ Gives the owners ideas to make the buildings energy efficient.
▪ There are three methods by which we can carry out energy assessment (Wang et al. 2012).
o Calculation based method
o Measurement based method
o Hybrid method
▪ Hybrid method is being used in our project where we are using both simulated (calculations) as well as measurement based data.
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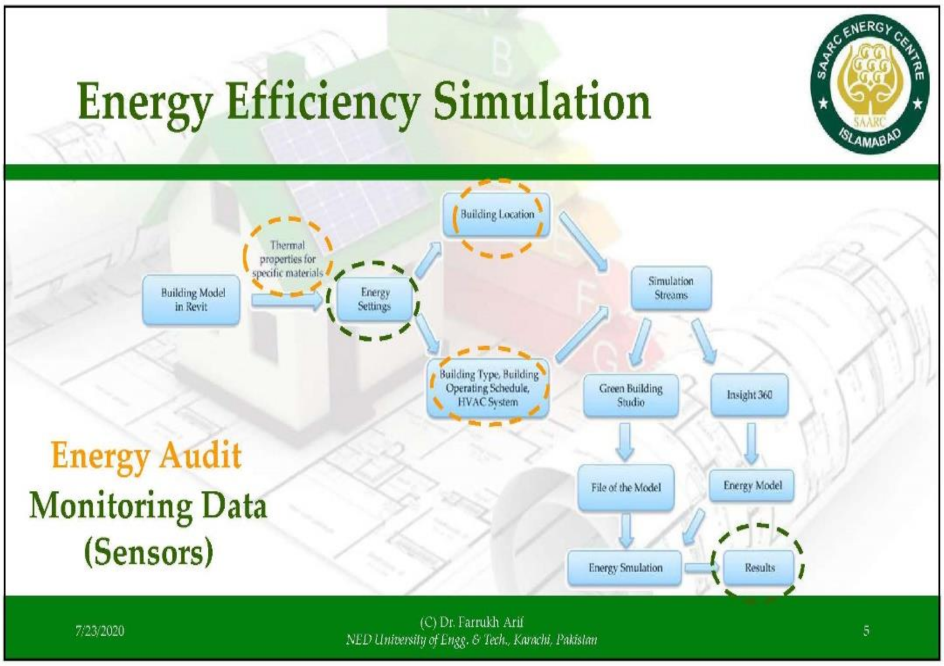
Energy Efficiency Simulation
SAARC ENERGY CENTRE
SAARC
ISLAMABAD
Building Model in Revit
Thermal properties for specific materials
Energy Settings
Building Location
Building Type, Building Operating Schedule, HVAC System
Simulation Streams
Green Building Studio
Insight 360
File of the Model
Energy Model
Energy Simulation
Results
Energy Audit
Monitoring Data
(Sensors)
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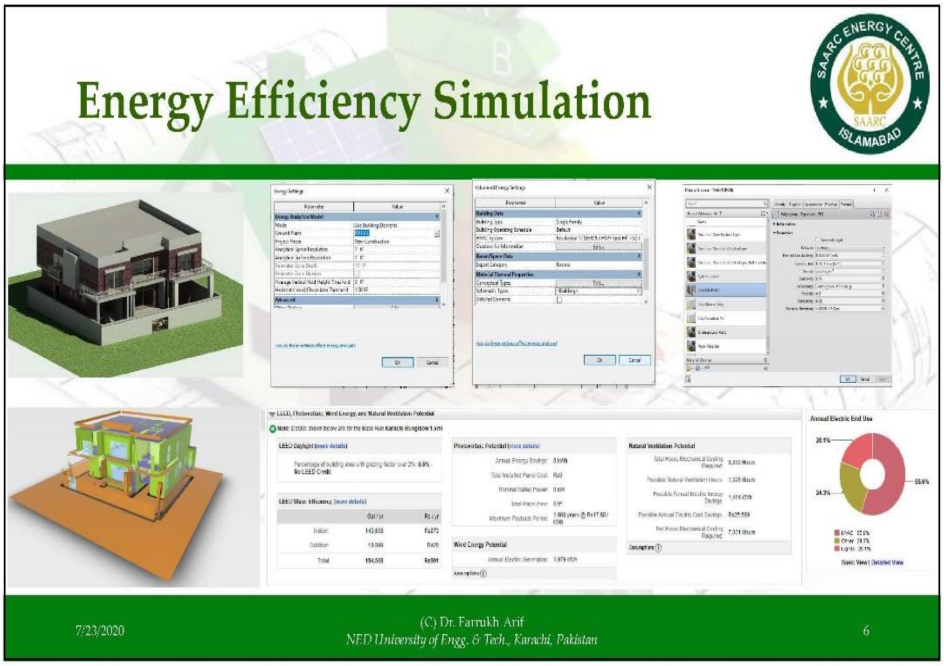
Energy Efficiency Simulation
SAARC ENERGY CENTRE
SAARC
ISLAMABAD
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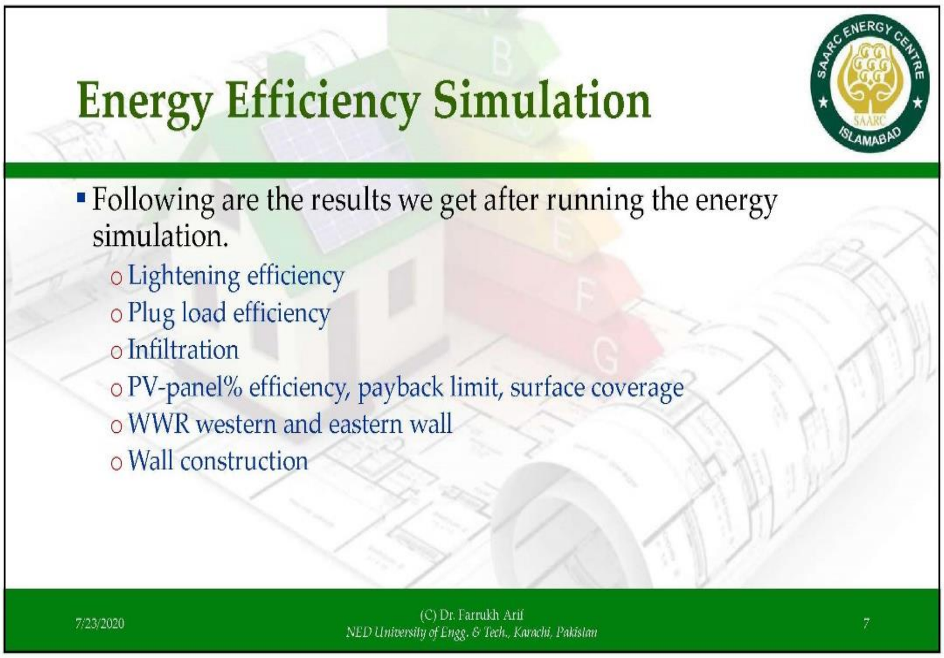
Energy Efficiency Simulation
Following are the results we get after running the energy simulation.
Lightening efficiency
Plug load efficiency
Infiltration
PV-panel% efficiency, payback limit, surface coverage
WWR western and eastern wall
Wall construction
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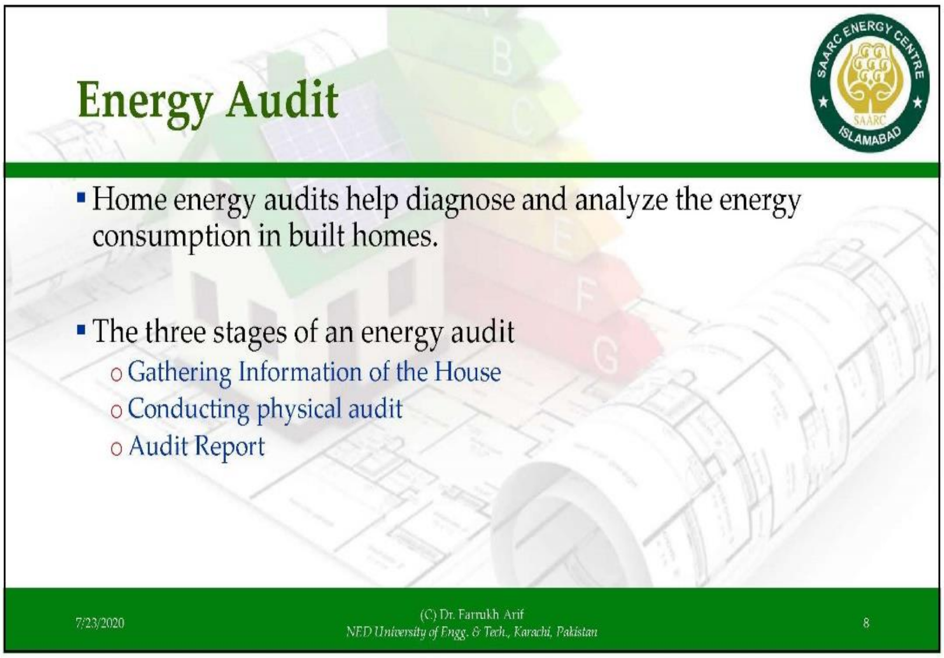
Energy Audit
Home energy audits help diagnose and analyze the energy consumption in built homes.
The three stages of an energy audit
Gathering Information of the House
Conducting physical audit
Audit Report
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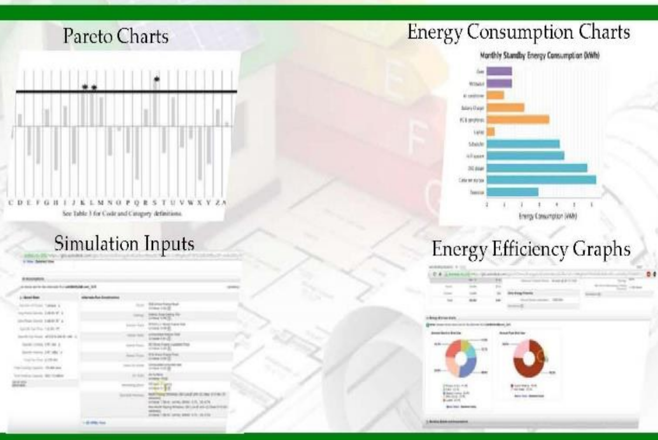
Energy Audit

- Energy Audit Checklist
  - Building envelope
  - Lightning Power Density
  - Material Properties
  - Energy Profile of Appliances
  - Alternative Energy input
  - Heating and cooling loads
- Material Properties
  - Thermal transmittance (U-Value) measures the rate of heat transfer.
  - Thermal resistance (R-Value) is its direct measure of resistance to transferring heat.
- U and R-Value describes the thermal performance of a building's fabric.
- Relation with energy efficiency
  - Lower the U value of a material (fabric).
  - The higher the R value of a building material.

Energy Audit Outputs



Living Lab Concept

- Provides Real-world experimental environment.
- "Primarily conducting research in real world contexts in order to tackle the real world problem of needing to increase energy efficiency" (Følstad 2005).
- Living Lab set-up can also help investigate whether involvement in the ICT-based user interfaces can affect behavior change towards energy efficiency.
- Living lab concept is being utilized
  - Gather data required for energy efficiency assessment.
  - For physical validation of the guidelines developed through analytical and experimental data analysis.

Living Lab Setup

- "Three room Living Lab Sensor Setup" for a built house for assessment of energy efficiency parameters
- System Assessment Includes;
  - Indoor Temperature
  - Humidity
  - Directional Light Intensity
  - Pressure
  - Voltage Monitoring on appliances
  - Current Monitoring on Appliances
  - Weather Station based sensing for various outdoor properties including wind energy potential and Solar Potential.
- A house will be monitored for at least a month.
- Different houses in an years' time in different seasons and districts of Karachi.


Sensor Based Assessment
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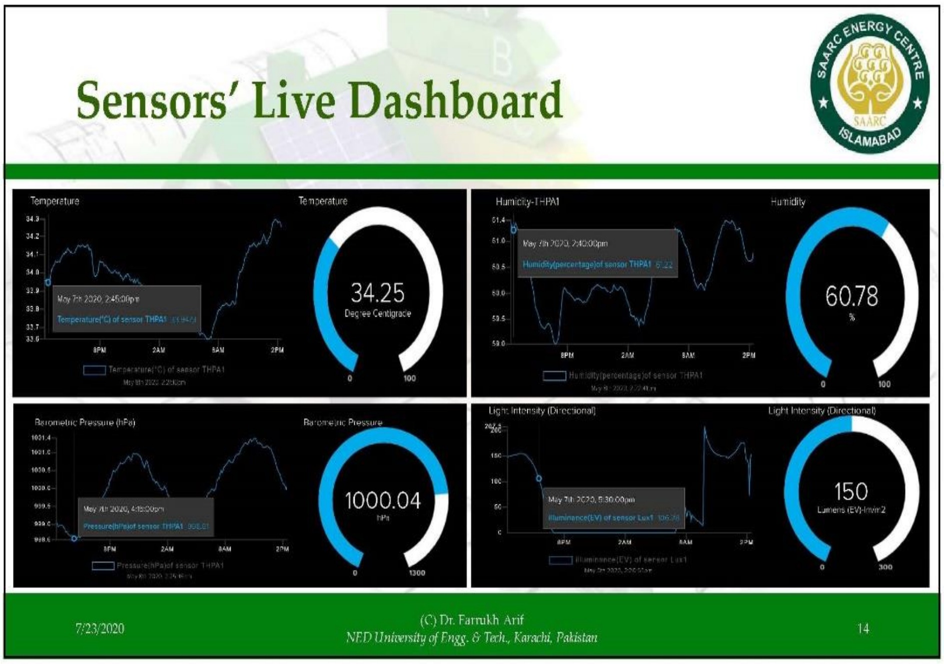
Sensors' Live Dashboard
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SAARC
ISLAMABAD
Temperature
Temperature
34.25
Degree Centigrade
Humidity-THPA1
Humidity
60.78
%
Barometric Pressure (hPa)
Barometric Pressure
1000.04
Light Intensity (Directional)
Light Intensity (Directional)
150
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▪ European Commission, (2006), 'Action Plan for Energy efficiency 2007–2012',/http://europa.eu/legislation_summaries/energy/energy_efficiency/l27064_en. htms.
▪ Wang, S., Yan, C., and Xiao, L. (2012). "Quantitative Energy Performance Assessment Methods for Existing Building." Energy and sBuildings (55), 873-888.
▪ Følstad, A. (2008). "Living Labs for Innovation and Development of Communication Technology: A Literature Review", The Electronic Journal for Virtual Organisations and Networks 10: 99-131.
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