INDEX

СНАРТ	ER-I INTRODUCTION	1 – 15
1.1	Importance of Energy Management in Commercial Buildings	1
	1.1.1 Economic Benefits	2
	1.1.2 Environmental Impact	2
	1.1.3 Regulatory Compliance and Market Trends	2
	1.1.4 Social Responsibility	2
	1.1.5 Technological Innovations	3
1.2	Role and Potential of IoT in Enhancing Energy Efficiency	3
	1.2.1 Real-Time Energy Monitoring	3
	1.2.2 Automated Control Systems	3
	1.2.3 Predictive Maintenance	4
	1.2.4 Demand Response and Load Management	4
	1.2.5 Enhanced Decision Making	4
	1.2.6 Integration with Renewable Energy	4
	1.2.7 Smart Grid Compatibility	5
1.3	Smart Buildings: Revolutionizing Modern Infrastructure	5
	1.3.1 Key Features of Smart Buildings	5
	1.3.2 Challenges and Future Outlook	6
1.4	Importance/ Rational of proposed Investigation	7
1.5	Research Gaps	12
1.6	Problem Statements	13
1.7	Aim	14
1.8	Objectives of The Proposed Study	14
1.9	Scope	14
1.10	Hypothesis	15
СНАРТ	ER- II REVIEW OF LITERATURE	16 – 38
2.1	Overview of Existing Energy Management Systems	16
	2.1.1 Traditional Energy Management Systems	16
	2.1.2 Key Components of Traditional EMS	18
	2.1.3 Key Components of Traditional EMS	18
	2.1.4 IoT-Enabled Energy Management Systems	19

2.2	IoT in Energy Management	21
2.2	2.2.1 IoT Technologies in Energy Management	21
	2.2.2 Smart Sensors and Meters	23
	2.2.3 IoT-Enabled HVAC Control	23
	2.2.4 Intelligent Lighting Systems	23
	2.2.5 Predictive Maintenance	24
		24
2.2	č	24
2.3	Energy Management Software as a Service (SaaS)	
2.4	Integrated Building Management Systems (IBMS)	27
2.5	Use of Renewable Energy Systems	29
2.6	Behavioural Impact on Energy Consumption	31
2.7	Gaps in Current Research	35
2.8	Previous Findings, Gaps, and How This Research Aims to Fill	37
	These Gaps Previous Findings	
СНАРТ	ER-III RESEARCH METHODOLOGY	39 - 63
3.1	Research Design	39
	3.1.1 Quantitative Design	39
	3.1.2 Qualitative Design	20
	J.I.2 Quantative Design	39
3.2	Research Questions and Hypotheses	40
3.2 3.3		
	Research Questions and Hypotheses	40
	Research Questions and Hypotheses Data Collection Methods	40 41
	Research Questions and HypothesesData Collection Methods3.3.1Primary Data Sources	40 41 41
	Research Questions and HypothesesData Collection Methods3.3.1Primary Data Sources3.3.2Secondary Data Sources	40 41 41 42
3.3	Research Questions and HypothesesData Collection Methods3.3.1Primary Data Sources3.3.2Secondary Data Sources3.3.3Data Collection Instruments	40 41 41 42 42
3.3	Research Questions and HypothesesData Collection Methods3.3.1Primary Data Sources3.3.2Secondary Data Sources3.3.3Data Collection InstrumentsSample Selection	40 41 41 42 42 42 45
3.3	Research Questions and HypothesesData Collection Methods3.3.1Primary Data Sources3.3.2Secondary Data Sources3.3.3Data Collection InstrumentsSample Selection3.4.1Description of the Sampling Strategy	40 41 41 42 42 42 45 45 45
3.3	Research Questions and HypothesesData Collection Methods3.3.1 Primary Data Sources3.3.2 Secondary Data Sources3.3.3 Data Collection InstrumentsSample Selection3.4.1 Description of the Sampling Strategy3.4.2 Sampling Procedures	40 41 41 42 42 45 45 45 46
3.3	Research Questions and HypothesesData Collection Methods3.3.1 Primary Data Sources3.3.2 Secondary Data Sources3.3.3 Data Collection InstrumentsSample Selection3.4.1 Description of the Sampling Strategy3.4.2 Sampling Procedures3.4.3 Handling Potential Biases	40 41 41 42 42 45 45 45 45 46 46
3.3	Research Questions and HypothesesData Collection Methods3.3.1 Primary Data Sources3.3.2 Secondary Data Sources3.3.3 Data Collection InstrumentsSample Selection3.4.1 Description of the Sampling Strategy3.4.2 Sampling Procedures3.4.3 Handling Potential BiasesData Collection Procedures	40 41 41 42 42 45 45 45 45 46 46 46 47
3.3	Research Questions and HypothesesData Collection Methods3.3.1 Primary Data Sources3.3.2 Secondary Data Sources3.3.3 Data Collection InstrumentsSample Selection3.4.1 Description of the Sampling Strategy3.4.2 Sampling Procedures3.4.3 Handling Potential BiasesData Collection Procedures3.5.1 Detailed Procedure for Sensor Data Collection	40 41 41 42 42 45 45 45 46 46 46 47 47
3.3	Research Questions and HypothesesData Collection Methods3.3.1 Primary Data Sources3.3.2 Secondary Data Sources3.3.3 Data Collection InstrumentsSample Selection3.4.1 Description of the Sampling Strategy3.4.2 Sampling Procedures3.4.3 Handling Potential BiasesData Collection Procedures3.5.1 Detailed Procedure for Sensor Data Collection3.5.2 Detailed Procedure for CCTV Data Collection	40 41 41 42 42 42 45 45 45 46 46 46 46 47 47 47 48

INDEX

3.6	Data Processing and Analysis	49
	3.6.1 Data Pre-processing	49
	3.6.2 Analysis Techniques	50
	3.6.3 Tools and Software Used	51
3.7	Development of Decision Models	51
	3.7.1 HVAC Optimization Model	51
	3.7.2 Lighting Optimization Model	52
	3.7.3 Occupant Behaviour Model	53
	3.7.4 System Integration	53
3.8	System Integration	54
	3.8.1 Combining All Models into a Unified System	54
	3.8.2 User Interface Development	55
3.9	Validation and Testing	56
	3.9.1 Validation Procedures	56
	3.9.2 Pilot Testing	57
	3.9.3 Adjustments and Improvements	58
3.10	Ethical Considerations	58
	3.10.1 Data Privacy and Security	58
	3.10.2 Compliance with Ethical Guidelines	59
	3.10.3 Ensuring Ethical Use of IoT Technology	60
	3.10.3 Ethical Reporting and Dissemination	60
3.11	Limitations of the Methodology	61
	3.11.1 Discussion of Potential Limitations	61
	3.11.2 Mitigation Strategies	62
CHAPT	ER- IV RESULT AND DISCUSSION	64 - 84
4.1	Computer Vision-Based Occupant Behavior towards Energy in	64
	Commercial Premises Using CCTV Footage	
	4.1.1 Person Detection Accuracy	64
	4.1.2 Illumination Level Measurement	65
	4.1.3 Taguchi Design of Experiment Analysis	66
	4.1.4 Contour Plots	67
	4.1.5 Window and Person Detection Algorithms	69
4.2	Smart Building Control System Driven by Occupancy for	70

INDEX

	Enhanced Energy Efficiency	
	4.2.1 System Efficacy	70
	4.2.2 Energy Efficiency and Occupant Comfort	70
4.3	IoT-based Temperature Monitoring and Data Analysis for	71
	Occupant Behavior in Commercial Buildings	
	4.3.1 Temperature and HVAC Performance	71
	4.3.2 Outdoor Temperature and Energy Consumption	73
	4.3.3 Occupant Behavior and Energy Usage	73
	4.3.4 Temperature and Humidity Monitoring	73
	4.3.5 Occupant Behavior Analysis	74
	4.3.6 Data Visualization and Analysis	77
	4.3.7 Algorithm Performance Evaluation	78
	4.3.8 Temperature Monitoring and Control	81
4.4	Summary	82
4.5	Discussions	83
CHAPT	ER-V CONCLUSION	85 - 87
5.1	Contributions to the Field	85
5.2	Implications for Practice	86
5.3	Limitations and Future Research	86
REFERI	ENCES	88 – 97
PAPER	PUBLICATION	
CONFE	RENCE CERTIFICATE	

LIST OF TABLE

Table No.	Particulars	Page No.
2.1	Behavioural Impact on Energy Consumption	33
4.1	Person Detection Accuracy Analysis	65
4.2	Illumination Level Analysis	66
4.3	HVAC Energy Consumption Analysis	73
4.4	Temperature and Humidity in Rooms	76

LIST OF FIGURE

Fig. No.	Particulars	Page No.
1.1	Importance of Energy Management in Commercial	1
	Buildings [9]	
1.2	Percentage of power consumption	8
1.3	Energy management solution [10]	8
1.4	Feedback to occupants based on energy-aware behaviour [2]	9
1.5	Graphs of indoor temperature and power consumption	10
	versus time as gathered by sensors [6]	
1.6	Power supply system of a shopping mall [26]	10
1.7	To facilitate energy management, their suggested system	11
	collects, analyses, and shows data from four primary sets	
	of indicators collected using IoT system [39]	
1.8	Placement of components in an IoT-based energy	12
	management system [7]	
2.1	Energy management system architecture and operation	16
	[24]	
2.2	IoT-Enabled Energy Management Systems [1]	19
2.3	Energy Management Software as a Service (SaaS)	25
2.4	Integrated Building Management Systems (IBMS)	27
2.5	Renewable energy systems integration to energy	29
	management in buildings	
3.1	Research Methodology Flow Chart	44
4.1	Mean of means plot obtained with Taguchi design of	65
	experiment analysis	
4.2	Contour plot of energy efficiency with respect to person	68
	detection and indoor lighting	
4.3	Contour plot of energy efficiency with respect to outdoor	69
	lighting and indoor lighting	
4.4	Contour plot of energy efficiency with respect to person	70
	detection and outdoor lighting	

4.5	(a) The output of the Window Detection Algorithm is denoted by the red bounding box. (b) The output of the Person Detection Algorithm is indicated by the yellow bounding box	71
4.6	The LCD output of an IoT circuit with a Raspberry Pi Pico	72
4.7	Measurement hardware in 3 different types of cabin (a) Large cabin (b) Medium-sized cabin (c) Small cabin. A magnified version of the circuit is shown in Fig (a)	74
4.8	HVAC temperature monitored by our IoT device over 3 different days where outside temperature varied between 30.5 to 35.2 degrees Celsius in summer	75
4.9	(a) Layout of the mobile app built for collecting all the data from all IoT sensors. The app was built using Thunkable and used with the "Firebase" database, which was used for collecting information remotely. (b) A picture of the actual app running on the mobile device. (c) Sample temperature plot gathered for testing IoT devices with Thingspeak channel. (d) Sample humidity plot shown on Thingspeak's front-end UI interface	78
4.10	displays the results of the window detection algorithm under different lighting conditions. Subfigure (a) shows the output in a scenario with no indoor lighting, where the absence of illumination might pose challenges for ac- curate window detection. In contrast, subfigure (b) depicts the output when sufficient indoor lighting is present, facilitating clearer visibility and more accurate detection of windows within the monitored area	79
4.11	Output of window detection algorithm with (a) no light condition at indoor (b) Sufficient indoor lights	79
4.12	Output of all algorithms running simultaneously: (a) Wastage of energy situation (b) Useful case of lighting as person is doing the work	80

4.13	Time in min vs temperature plot showing both Actual vs. Measured	81
4.14	Time in min vs temperature plot for Set-point and actual output	82