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A Review of Energy Proficient Buildings as a strategy towards Energy conservation in Pakistan

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Abstract-With increasing population demands, there is a constant noticeable need for energy supply. In this scenario various methods have been devised to meet these energy demands to ensure its viable resource. There has been a noticeable energy crisis situation in many countries like Pakistan that has badly affected its financial and developmental stability. This paper aims to first review the efforts that are being made by the related departments to address this dilemma based upon the conservation policies and building bylaws followed by discussion on key areas like building design, layout and orientation, thermal insulation and day lighting as parameters to be addressed in this area of research. This study is an effort to highlight the need of energy proficient buildings, thus making our cities energy proficient cities and other solutions in Pakistan keeping in view of the energy preservation and proficiency as architectural design solutions. The research concludes that the devising energy proficient buildings thus developing energy proficient cities in Pakistan we can save significant energy for our daily use that will affect our economy directly.

Keywords-Energy Crisis, Building Orientation, Daylighting, Energy Proficient Buildings

I. INTRODUCTION

Pakistan has been facing a severe energy crisis for the last decade. Rapid urbanization led to great pressures on power and natural gas distribution system. One of the reasons for this situation found was the institutional shortcomings and over-reliance on expensive furnace oil for power generation. High power grid system losses due to theft and low-efficiency mechanisms took out a major portion of our power generation capabilities with electricity shortfall averaging at 5000Mega Watts (MW) during peak summer season [i]. Power shortages led to a loss of nearly $3.9 billion dollars in the year 2009 which is 2.5% of the GDP [ii]. Power generation and distribution companies are still entrapped in 'circular debt' as they are not able to recover the full cost of production. The situation appears grave considering that Pakistan has very low energy consumption per capita compared with global levels. More developed countries have much higher energy consumption per capita due to greater industrial penetration and automated processes. Even with such a low energy consumption per capita, a majority of Pakistanis suffer 6-8 hours of rolling blackouts (load-shedding), as fresh generation capacity can't match up with the growing energy demands of the nation [iii].

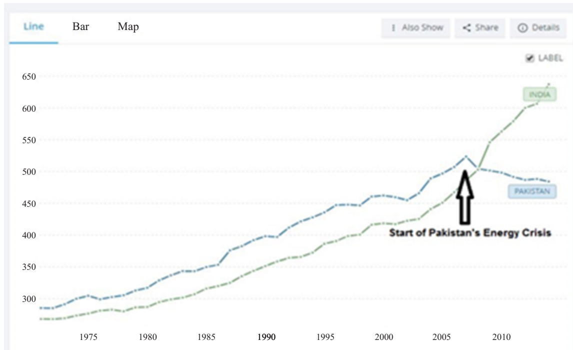

Fig. 1. ENERGY CRISIS Pakistan Energy Use (kg of oil per capita)
Source-The World Bank (IEA STSTISTICS)

In this whole debate, the most neglected topic has been the conservation of energy. Pakistan has enormous potentials to save valuable resources if principles of energy efficiency and sustainable growth are incorporated into various sectors of the economy. These sectors include industry, transportation, agriculture and building construction sectors. This paper will focus on the potentials of smart, energy-efficient buildings in creating smart cities which can ultimately lead to energy savings at the national level and lead to sustainable growth. The role of various government institutions in promoting and enforcing rules of energy efficiency will also be discussed in the paper. Residential and commercial building sector consumes a significant portion of the total energy intake of the country and can achieve a tremendous

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amount of energy savings just by following simple instructions and choosing the right electrical appliances. Energy efficient buildings and cities can better cope with power crunch and help Pakistan improve its productivity.

II. Energy Proficient Buildings and its Importance

Generally speaking, Energy proficient buildings conserve resources by using modern technology and principles of sustainability. The term Smart Building means "a collection of technologies utilized to make the design, construction and operation of buildings more efficient" [iv]. They operate on the preferences of occupants, by incorporating the feedback both from and to such occupants about their use of building [v]. They also integrate control, intelligence, materials and construction with adaptability not reactivity, at its core, to achieve energy efficiency, comfort and longevity. Another term used frequently in this regard is the Zero-Energy Building (ZEB) which represents a building with very high levels of energy efficiency through minimization of external energy demand. This is achieved by efficient building designs adapted to the local climate coupled with building techniques which curtail its overall energy demand. ZEBs have zero carbon emissions on annual basis and are achieved through on-site renewable energy sources to meet the energy requirements [vi].

Energy proficient buildings and ZEBs have been studied extensively as they have the greatest potential to create smarter cities by contributing heavily towards the energy aspects of such modern cities through proper energy management. Viable scenarios for developing highly energy efficient buildings and communities in Cyprus has been studied and the analysis indicated that on an average the annual energy consumption of buildings in Cyprus can be reduced to 65 kWh/m_2 [vii] Intelligently designed ZEBs can act as the key ingredient of eco-city development, creating greener built environments [viii].

Globally, energy utilized by the building sector, consisting of both commercial and residential users, accounts for 20.1% of the total delivered energy. Buildings designed with adequate energy saving mechanisms may cost 15-20% more [ix]. In Pakistan, building sector operates on an excess use of concrete and glass, with a heavy reliance on energy inefficient space conditioning equipment. Various estimates have shown that energy proficient buildings can lead to minimum 30% saving in energy costs compared with a building designed with conventional inefficient provisions. ENERCON estimated that energy efficient building design can reduce electricity bills by 20% and this percentage can be increased to 50% if energy efficient appliances are utilized.

III. Materials and Methods

Pakistan has all the possible strength to conserve energy in all segments, which can be used to lessen the current energy crisis. This research paper is a review paper that attempts to focus on current energy consumption and potential savings potential in the country's housing sector as a designer's point of view looking into basic building parameters in terms of building design layouts and its orientation. The methodology adopted in this paper is a methodical data collection for which various field visits were made in order to obtain the required data regarding energy use in the residential sector and the other figures studied and adopted from various researches done. This study highlights the basic design characteristics of energy proficient buildings which need to be discussed and implanted in our buildings.

IV. Results and Discussions

A. Building Design, Layout and Orientation

Building design plays the pivotal role in conserving energy consumption. First and foremost is the building envelope which has the potential to save 40% of energy consumed by the building. It includes building's location, geometry, walls, nature, roofing qualities and windows. It means that nearly half of the energy saving potentials can easily be achieved if standard building energy codes are followed while designed the building's envelope. Building mass also plays a vital role here, as massive construction yields lower temperature inside the buildings during the daytime but may result in considerably higher temperatures at the night time as the absorbed heat in the structure finally reaches the interior space [x]. Lighter buildings act the opposite and have higher temperatures in the daytime but also have the ability to cool down faster during night times. Buildings should always be designed according to their usage. Office buildings which are supposed to be used predominantly during daytimes should have massive construction while hostel rooms which are utilized most during night times should have lighter construction. Building's interior layout should also be designed to minimize energy demand especially when it comes to residential buildings. There should a core area consisting of rooms used most frequently. Rooms which are foreseen to have less occupancy should be placed outside the daily traffic pattern so that they have minimal heating, cooling and lighting requirements. For example, placing storage room and guest bedrooms in a separate wing is helpful from the energy conservation perspective. Generally, large spaces should be kept outside the daily traffic pattern.

Building orientation is also important for passive cooling and heating purposes so that the dwellers can extract the maximum out of sunlight in terms of heating and natural light. In the city of Lahore, solar statistics for the winter season show that solar radiations are much higher on southern orientation and lesser in the east-west orientation. Whereas in the summers, the impact is reverse and western exposure is most troubling due to significantly higher afternoon temperatures. For the Lahore city, experimental and simulation results have shown that the South-West orientation is best for heating and cooling requirements [xi].

The factors such as the appearance of the site, building orientation, geometry and size of the windows and the skylights must be well thought out and carefully studied to effectively apply the sunlight to a space. Table 1 summarizes these factors in three categories: the site layout, the building geometry and the opening parameters. A useful guide on how good site planning can contribute to reaching the sunlight in buildings [ix].

TABLE I
FACTORS WHICH INFLUENCE THE AVAILABILITY OF DAYLIGHT IN BUILDINGS

Categories	Factors affecting daylight performance
Site layout	External obstructions (existing buildings and trees)
	Overshadowing
	Building orientation
Building geometry	Balconies and overhangs
	Extension to the existing building, which is perpendicular to the window
Opening parameters	Window sizes and parameters (height of window head from floor level)
	Roof light parameters

A reasonable building board can reduce the energy consumption of heating and air conditioning. From the point of view of thermodynamics and aerodynamics, the smaller body shape is proportional to the smallest external load. And the use of dwellings to ensure the energy efficiency of the external load stability has been made by the main factors [xii].

B. Thermal Insulation

Thermal insulation of roofing structure leads to significant energy savings. CDA and ENERCON performed a study on this topic in collaboration with the UN-HABITAT [ix]. The motive of the study was to find economical solutions to improve the thermal performance of roofs. These techniques were divided into three categories; reflective surface techniques, insulation techniques and radiant barrier techniques. Insulation materials like the polystyrene (jumbolon), mud with high-density Styrofoam (thermo-pore), stabilized mud, concrete tiles etc. were considered during the study. There was a considerable reduction in heat penetration when light color materials are applied to the roof surface. These materials include white enamel paint, lime wash, weather shield white paint and aerosol heat reflective paint. False ceiling materials which create a radiant barrier are cheap and highly effective.

TABLE II
REALIZABLE SAVINGS, INVESTMENT REQUIREMENTS AND SCHEDULE FOR INSTALLING ROOF INSULATION.

	Energy Efficiency Potential			Realizable Savings		Investment Required	Simple Payback Period	
	Technical	Realizable	Effective	(GWh)	(TOE)	($ Million)	Fin. (Yrs)	Eco. (Yrs)
Roof Insulation	20%	100%	20%	1,047	149,634	3,826	43	48

($ Million)

	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
Annual Cumulative		38	230	689	1,110	1,033	536	153	38	
		38	268	956	2,066	3,099	3,635	3,788	3,826	

Source: ADB, 2009 (Savings from Roof Insulation for Residential Sector)

An overall reduction of 2 to 3 degrees was observed in houses with insulation due to improved thermal performance. Paper board false ceiling is the least costly solution while paint insulation is the most expensive of all the options. Insulation is not limited to roofs only. Energy savings of much greater extent can be achieved if insulation materials are used in the building walls too. However, prevailing building construction norms in Pakistan don't allow wall insulation, which needs to change. An average building structure made of cement, concrete or baked clay blocks don't provide the required space for insulation materials. Walls with appropriate thickness require studs of the same width which are strong enough to bear the pressure [xiii]

Windows can lead to greater heat loss or gain than any other part of the building fabric. It is pertinent to choose the right size and glazing material to improve the thermal efficiency of buildings. Double-glazed glass windows have the greater insulation capacity than normal windows. Ideally, north facing windows should be of a greater area to utilize the heat from the winter sun, while east and west facing sides should have a minimal window area.

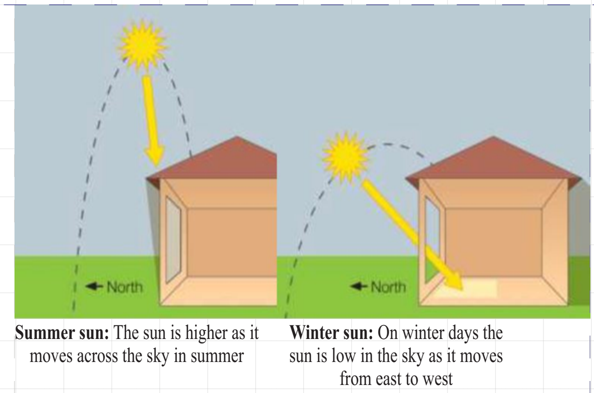

Fig. 2. Sun Movement in summer and winter season
Source: Dr. Ashfaq Ahmed Sheikh "Energy Efficient Buildings", 2014

C. Building Lighting

Buildings should be designed in a manner to reduce the need for artificial lighting during daytime to the maximum extent. In a recent study conducted in a similar climate like that of ours, it has been discovered that artificial lighting constitutes about 60% of the total energy consumption as far as commercial building sector is concerned. (Fig-3)

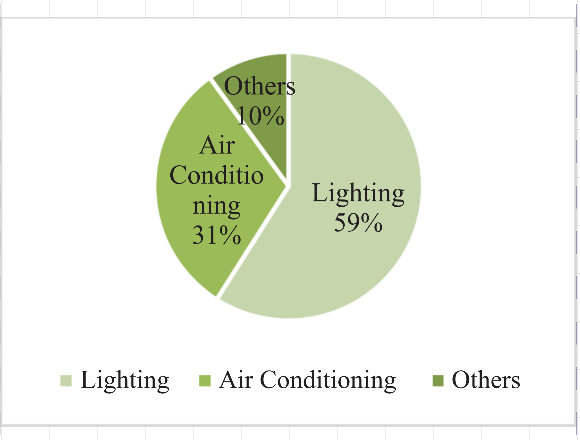

Fig. 3. Energy Use Breakdown in commercial Buildings India
SOURCE: Rashid M, et. Al, 2016

In the energy ranking of the buildings, the illumination of the building is the number one election. In some commercial buildings, lighting consumption, sometimes consumes more than 30% of total energy consumption. Due to the illumination factor, some need to reduce the temperature of the regional environment, since the heating of the lighting, which results in a load of the cooling system, is passive. The illumination of daylight represents the introduction of sunlight into the interior of the building and is assigned in a certain way to provide better lighting based on man-made light. The daylight reduces the need for light sources and reduces energy consumption and environmental pollution. Research shows that solar lighting can create a healthier and more dynamic environment than artificial lighting systems, which can increase productivity by 15%. Illumination can also change the intensity of light, color and vision, and help improve work efficiency and learning efficiency. Widely used in green buildings [xiv].

In Pakistan, a majority of the residential inhabitants prefer to block out the natural light using curtains or blinds which lead to increased electricity bills. Seemingly, the culprit here is the 'glare' from window areas, which is not related to brightness or the size of the light source but of the contrast. It is easily observable in office spaces which are lit from one side as the contrast between window wall and windows will lead to glare. Such places tend to have a gloomy outlook in the absence of artificial lighting. Lighting from two opposite sides or adjacent walls can rectify this situation.

Lighting appliances consume nearly 34% of the total energy utilized by the buildings whose share in Pakistan is nearly 12.2 TWh/year. Incandescent bulbs consume around 2.76 TWh/year. This has been calculated assuming their total number to be 30 million, out of which 3/5th of the bulbs are of 100 Watts while 2/5th are of 60 Watts. If these highly inefficient bulbs are replaced with 13 Watt LED bulbs and 40 Watt Fluorescent Lights than the total energy saved comes out to be 1.54 TWh/year [xvi]. Moreover, use of motion sensors and internet controlled light switches/bulbs can lead to much more cost savings as they can automate the lighting operation [xvii]. In developed countries, smart bulbs connected to virtual assistants controlled through smart phones are becoming a household item.

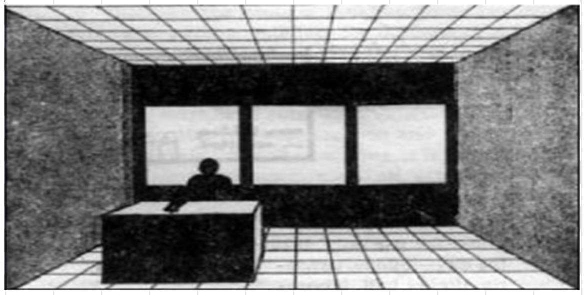

Fig 3. Glare due to Day lighting from one side

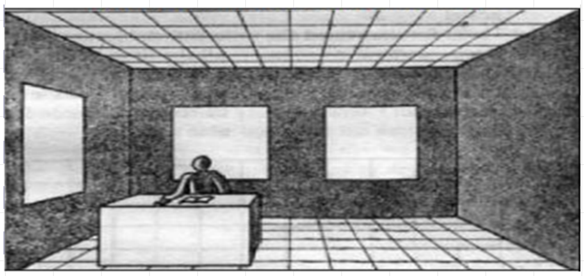

Fig. 4. Improved Lighting with windows on two walls
Source: Dr. Ashfaq Ahmed Sheikh "Energy Efficient Buildings", 2014

D. Space Cooling and Heating

Space heating and cooling represent a big source of energy consumption in Pakistan. In summers, air conditioning load presents a good percentage of residential sector's total energy consumption taking up 3000MW from national power production. Air-conditioning consumes around 17% of residential sector's electricity consumption. Most of the air-conditioning systems are old and energy inefficient with a rated wattage of around 1.7kW to 2.2kW [xviii].Inverter type energy-saving air-conditioning systems are yet to cement their place in the consumer appliance market due to their higher initial costs. Moreover, common operating practices in Pakistan also render air-conditions energy inefficient. For example, according to an estimate, 0.677 TWh of energy can be saved just by operating air-conditions at 23 degrees Celsius. Appropriate usage of motion sensors in this regard can lead to 15-20% more savings, as they can detect room occupancy and adjust output accordingly. Some building design techniques can also lead to higher operational efficiency for air-conditioning systems, like placing the outdoor units in shaded areas away from direct sunlight. Fans, refrigeration and water pumping systems also present a great room for improvement in their energy efficiency ratings.

TABLE III
ENERGY CONSUMPTION, REALIZABLE SAVINGS, INVESTMENT REQUIREMENTS AND SCHEDULE FOR REPLACING ELECTRICAL APPLIANCES

Energy Type	Energy Consumed. FY2008		Energy Consumption Forecast. FY2019		Energy Efficiency Potential			Realizable Savings FY2019		Investment Required	Simple Payback
	(GWh)	(TOE)	(GWh)	(TOE)	Technical	Realizable	Effective	(GWh)	(TOE)	($ Million)	Fin. (Yrs)
Refrigeration	748	60,908	2,615	212,935	67%	80%	54%	401	32,647	40	0.8
Air Conditioning	966	78,697	3,378	275,124	40%	80%	54%	401	32,647	40	0.8
Fans	1,671	136,051	5,840	475,633	0%	0%	0%				
Others	650	52,965	2,274	185,164	0%	0%	0%				
Total	4,035	328,621	14,107	1.148,856				710	57.830	60	
											($ Million)
	FY10		FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
Annual			0.6	3.6	10.8	17.4	16.2	8.4	2.4	0.6	59.9
Cumulative			0.6	4.2	15.0	32.3	48.5	56.9	59.3	59.9	

TABLE IV
ENERGY CONSUMPTION, REALIZABLE SAVINGS, INVESTMENT REQUIREMENTS AND SCHEDULE FOR REPLACING ELECTRICAL APPLIANCES
Source:IADB, 2009 (Energy Consumption and savings detail for residential sector

Energy Type	Energy Consumed,		Energy Consumption		Energy Efficiency Potential			Realizable Savings.		Investment Required	Simple Payback	
	(GWh)	(TOE)	(GWh)	(TOE)	Technical	Realizable	Effective	(GWh)	(TOE)	($ Million)	Fin. (Yrs)	Eco. (Yrs)
Refrigeration	4,524	368,424	10,550	859,176	67%	80%	54%	2,425	197,475	304	1.5	1.6
Water Pumping	1,258	102,422	2,933	238,852	50%	80%	40%	503	40,969	465	10.9	12.2
Air Conditioning	5,845	476,024	13,631	1,110,102	40%	80%	32%	1,870	152,328	149	0.9	1.0
Fans	10,105	822,950	23,565	1,919,143	0%	0%	0%					
Others	6,332	515,657	14,765	1,202,526	0%	0%	0%					
Total	28,064	2,285,477	65,444	5,329,799				4,798	390.772	918		

A bulk of Pakistan's energy requirements is fulfilled through natural gas. It consumed in power houses for electricity generation, by fertilizer plants as feedstock, in the transportation sector as Compressed Natural Gas (CNG) and in building sector for space and water heating along with cooking food. This has led to the severe natural gas shortfall, which peaks during the winter season when space heating demand surges. Most of the space and water heating appliances used in Pakistan are highly energy inefficient leading to monetary losses. It is estimated that there is a 36% potential to improve the energy efficiency of space heating appliances by replacing low-quality space heaters. This potential is calculated to be around 30% for water heating by retrofitting water heating appliances and gas utility companies have introduced these retrofits for water heating appliances at a minimal cost. Similarly, improvement potential for cooking appliances is estimated at 40%, which can be easily achieved by replacing older, inefficient stoves [xix] Building insulation plays an integral role in this regard which can drastically curtail energy costs in every season.

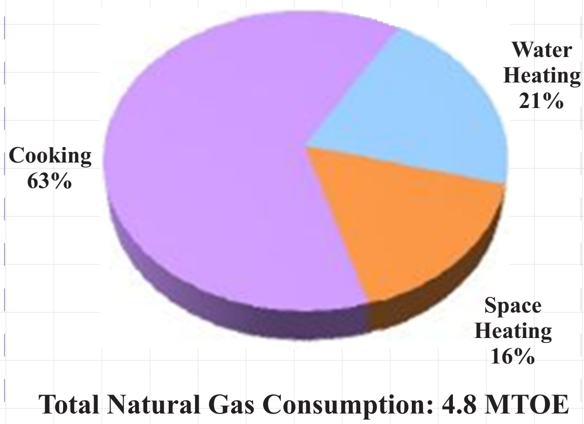

Fig. 5. Natural Gas consumption in Residential Sector by End-use
Source: ADB, 2009

TABLE V
ENERGY CONSUMPTION, REALIZABLE SAVINGS, INVESTMENT REQUIREMENTS AND SCHEDULE FOR REPLACING GAS APPLIANCES
Source: ADB, 2009 (Natural Gas Consumption & Savings Outlook for residential sector)

Energy Type Payback Period	Energy Consumed, FY2008 FY2019		Energy Consumption Forecast. Required FY2019		Energy Efficiency Potential			Realizable Savings		Investment
	(MMscf)	(TOE)	(MMscf)	(TOE)	Technical	Realizable	Effective	(MMscf)	(TOE)	($ Million)
Water Heating	42,241	988,441	98,507	2,013,679	30%	80%	24%	10,138	237,226	28
Space Heating	33,430	782,274	77,961	986,886	36%	80%	29%	9,628	225,295	99
Cooking	128,363	3,003,705	299,347	7,788,899	43%	80%	34%	43,644	1,021,260	52
Total	204,035	4.774.412	475,815	10.789.46	39%	80%	31%	63,409	1.483.780	179

E. *Weak Institutional Framework for devising and implementing Smart Building Codes*

Energy conservation is a relatively modern concept in Pakistan. Since the formation of Pakistan, the focus of governments has been towards energy generation rather energy conservation. The first effort in the form of Pakistan Energy Conservation program started with funding from USAID under the Pakistan Energy Planning & Development (EP&D) program in the year 1983. It led to the formation of the National Energy Conservation Center (ENERCON) in the year 1986. Basically, the restructuring of Planning & Development Ministry's Energy Wing led to the formation of ENERCON [xx]. However, ENERCON was never envisaged to become an environmental regulator or a watch-dog enforcement agency. It didn't possess the regulatory powers to curtail energy losses just like the Pakistan Environmental Protection Agency (PEPA).

Instead of regulation, ENERCON was designed to nurture the partnership between the public and the private sector in performing "energy audits" and provide guidelines for energy conservation in transportation, industrial, agricultural and building construction sectors. These energy audits were mostly subsidized or free-of-cost due to which they were welcomed generously by most of the business entities instead of facing any resistance. The basic aim was to deliver outreach, awareness and education in general and specific energy users. ENERCON also worked with various architectural schools to expand their curriculum to include energy conservation concepts in building design courses. In terms of practical works, ENERCON worked deeply to uplift the energy conservation profile of the construction sector through the diagnosis of insulation, lighting and cooling systems of various buildings [xx].

Pakistan Energy Conservation program continued till the year 1992. During that period, ENERCON performed forty-three energy surveys in private and government building structures. One hospital was able to save $224,000 in the year 1989 simply by adopting energy conservation guidelines offered by the institution [xxi]. However, the only national institution working diligently to promote energy conservation had to face severe bureaucratic jugglery once USAID funded parent program ended. ENERCON which started as a semi-autonomous body under the Ministry of Planning & Development was transferred to Ministry of Water & Power in the year 1993. In the year 1996, it was shifted to Ministry of Environment and then in the year 2011, it was transferred back to Ministry of Water & Power [xxii].

Now, the Federal government has replaced ENERCON by National Energy Efficiency & Conservation Authority (NECCA) through the National Energy Efficiency & Conservation Act 2016. Pakistan Energy Efficiency and Conservation Board (PEECB) has also been formulated through this legislation which will oversee the formation of NECCA [xix]. This board will comprise of Federal Minister for Water & Power as the chairman, Federal Secretary Water & Power as the secretary and federal secretaries of petroleum, finance, climate change, housing & works, science & technology, chairman OGRA & NEPRA, provincial secretaries of the designated departments, FPCCI nominee and five representatives of private sector as the members. NECCA will have the regulatory powers to enforce principles of sustainable development in every sector including the crucial construction sector. Enforcement of building codes and Minimum Energy Performance Standards for electrical appliances will be the responsibility of NECCA, which will be performed in coordination with the provincial authorities. Provincial Government of Punjab has also notified the formation of a provincial authority called Punjab Energy Efficiency & Conservation Authority (PEECA) which will assist NECCA in this regard.

In the year 2013, Pakistan Engineering Council (PEC) in collaboration with ENERCON and Ministry of Housing & Works did launch Energy Conservation Building codes (ECBC). The requirements covered aspects like the air-conditioning, building envelope, ventilation, lighting, service water heating. They are applicable to buildings with a minimum total connected load of 100 kilowatts or a contract demand of 125 kilovolt-ampere [xxiii]. However, their enforcement at the ground level has remained less than expected due to lack of regulatory regimes at various tiers of the government, but now with the enactment of NECCA, there are hopes of better service delivery. NECCA has been supervising a program under which consumer appliances are being labeled for minimum efficiency standards which will encourage the general population to buy energy efficient appliances. For that matter, NECCA and PECCA are planning to set up testing labs for fans, electric motors and air-conditioners at different academic institutions. Pakistan Standards & Quality Control Authority (PSQCA) is another state-run entity tasked with standardization and quality control for the improvement of industrial efficiency [xvii]. It has various testing facilities at its disposal to check the quality of products and assign appropriate labeling accordingly. Recently, it has signed MOUs with NECCA to promote energy efficient home appliances [xxiii].

Overall, the institutional framework surrounding smart, energy-efficient buildings is weak and often subject to changing's to changing political governments. Formation of NECCA is a positive sign but its parent board seems to be overly bureaucratic which can lead to serious delays in implementing energy efficiency schemes at the provincial and local levels. There is a need for more public education with regards to the promotion of energy efficiency standards, otherwise general public will continue to buy cheaper and inefficient appliances without caring for their long-term benefits.

IV. Conclusion and Recommendations

Presently, Pakistan is facing severe energy crisis. As per the designers understanding on the concept of energy saving there are two possible solutions to this crisis. The first solution is to consistently increase our power generation capacity that is surely in the hand of the governing bodies, whereas the second one is to conserve energy through building itself by adopting all the methods as discussed above. First solution requires more monetary resources while the second solution requires more public awareness and institution building as it is in the hands of both to get the building designed in that manner that it is energy proficient that may be able to cut down the energy consumption naturally instead of adopting other means for energy usage. Sadly, the institutional framework which can lead to mass adoption of energy conservation is either missing or too weak. Pitching ideas of energy conservation hasn't remained politically popular in Pakistan, especially within the trader and agriculturist communities as they aren't aware of its overall benefits. Federal and provincial governments also prefer to launch mega power projects while completely ignore the principles of sustainable and smart living. At the federal level, there has been a push from foreign donors like USAID and ADB to curtail energy losses and carbon emissions but these efforts have not been able to reach lower tiers of governments. Building codes are still energy inefficient and their enforcement by building control authorities is scarce due to lack of expertise and resources.

Potentials are enormous when it comes to energy conservation and Pakistani society. Billions of electricity units can be saved only through proper building design and replacing inefficient lightings, fans, air-conditioning and water-pumping systems in this sector. It will not only help us in lowering our energy bills but will allow our communities to develop energy proficient buildings which have the required electricity and technology to control every building parameter in an automated manner. These energy proficient buildings can act coherently to form smart cities where technology powered by electricity from sustainable sources can play the central role.

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