Energy Efficient Buildings to Save Energy in Pakistan*

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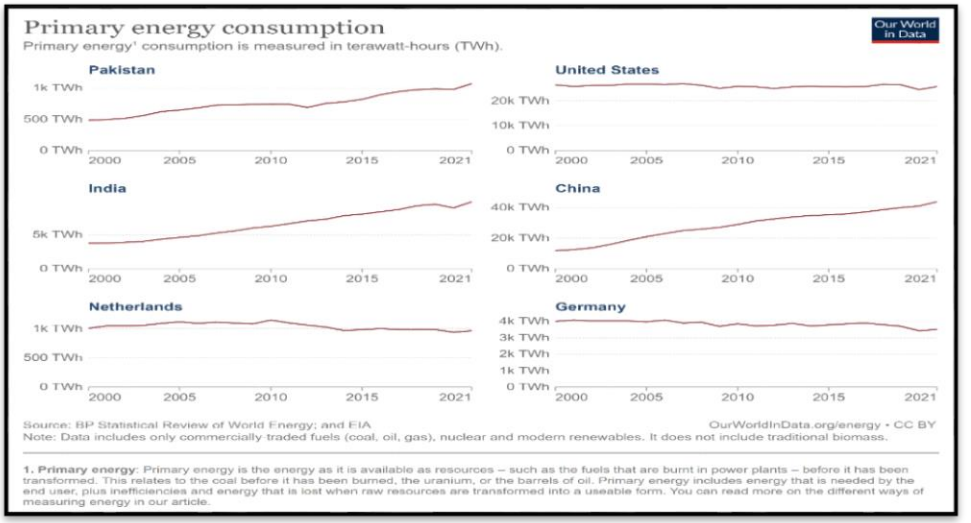
INTRODUCTION

Global energy consumption is increasing rapidly. Pakistan is also facing a severe energy crisis. A glimpse of energy consumption patterns in developing countries compared to those in developed countries depicts that energy consumption in developing countries, including Pakistan, has been rising (Figure 1).

Figure 1. Primary Energy Consumption since 2000



Source: https://ourworldindata.org/energy/country/pakistan?country=IND~CHN~USA~DEU~NLD~PAK#how-much-energy-does-the-country-consume-each-year

Since 2002, Primary Energy Consumption in Pakistan has increased from 484 terawatt-hours (TWh) in 2000 to 1071TWh in 2021[182]. However, the decline in energy consumption in developed countries like the United States, Germany, and the Netherlands manifests that these countries are becoming more energy efficient with time. By 2022, the Netherlands and Germany became the top energy-efficient countries in the world, with

* This chapter is completed in 2023.

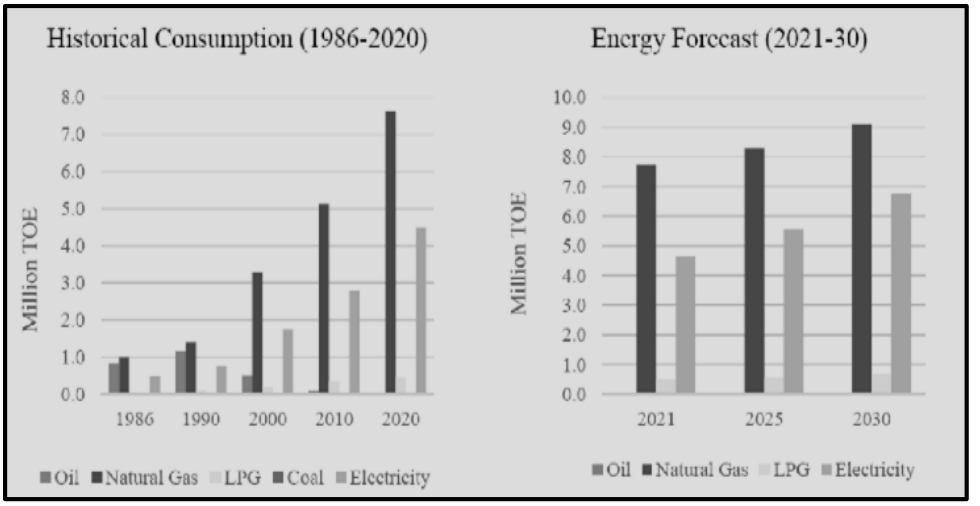
[182] https://ourworldindata.org/energy/country/pakistan?country=IND~CHN~USA~DEU~NLD~PAK#how-much-energy-does-the-country-consume-each-year

China and India in 9th and 16th positions, respectively[183], showing their efforts to be energy efficient. This knowledge brief offers a solution for sustainably managing the increasing energy demand in Pakistan's building sector.

ENERGY CONSUMPTION IN PAKISTAN

In Pakistan, electricity consumption in the domestic sector has risen continuously since 1986 due to rural electrification and urbanisation. Pakistan's total energy consumption is 60.21 MTOE[184]. By 2030[185], a spike in energy consumption is expected, such that natural gas consumption will be 55 percent, followed by electricity (40 percent) in the energy mix for the domestic sector (IEP, 2021) (Figure 2).

Fig. 2. Historical Energy Consumption & Energy Forecast in Domestic Sector in Pakistan



Source: IEP, 2021.

There are over 29 million households in the residential sector of Pakistan, consuming about 20.98 percent of the country's total energy consumption. The electricity consumption pattern in Pakistan is in stark contrast with the global trend: 48.5 percent of the total electricity consumption is in the domestic sector, followed by industry, which consumes 27.2 percent of the total electricity[186]. On the contrary, globally, more electricity is consumed in the industrial sector (41.9 percent) as compared to the domestic sector (26.6 percent)[187]. Even in India, industry consumes 41 percent of total electricity, while the domestic sector consumes only 26 percent[188].

[183] https://www.aceee.org/international-scorecard

[184] Pakistan Energy Yearbook 2021

[185] https://www.pc.gov.pk/uploads/report/IEP_Report_FINAL.pdf

[186] NEPRA State of Industry Report, 2022.

[187] https://www.iea.org/data-and-statistics/charts/world-electricity-final-consumption-by-sector-1974-2019

[188] https://www.statista.com/statistics/1130112/india-electricity-consumption-share-by-sector/

ENERGY CONSUMPTION IN BUILDINGS IN PAKISTAN

A major portion of energy is consumed to condition the buildings (residential, commercial, public, and private) during extreme weather conditions. One reason for high energy consumption in the buildings can be attributed to the construction materials and designs.

Looking deeper highlights that buildings have been constructed using thermally conductive materials without having the insulation capacity, making buildings warmer in the summers and cooler in the winters, leading to high energy usage for regulating the temperature.

For example, the energy demand in Pakistan fluctuates significantly between winters (12 KMW) and summers (32 KMW), with the high cooling load being the primary contributing factor. Domestic cooling accounts for nearly 37.10 percent of the total capacity, while commercial cooling contributes to approximately 65 percent of the total energy demand. The difference is around 20 KMW. Electricity has to be generated at high rates to meet this additional demand, resulting in high tariffs and capacity.

By 2025, the peak electricity demand in Pakistan is expected to increase by an additional 4000 MW. This gap is anticipated to widen due to various factors, including the growing electricity consumption in the building sector.

The buildings sector consumes more electricity than any other sector for space heating and cooling, refrigeration, cooking, lighting, etc. Effective Energy Efficiency and Conservation (EE&C) measures could save Pakistan up to 2.63 MTOE in energy in these areas[189]. Globally, in 2020, the building sector consumes 35 percent of the world's energy, with residential buildings accounting for 22 percent of that consumption (Abergel, 2020). Efficiently managing energy demand can reduce peak load during extreme seasons in the building sector.

ENERGY CONSERVATION BUILDING CODES FOR ENERGY EFFICIENT BUILDINGS

The demand for new construction in Pakistan is increasing. This presents a great opportunity to use energy-efficient equipment, materials, and practices to develop an improved building envelope to reduce energy wastage. For instance, due to high population growth and rapid urbanisation in Pakistan, there is a 5.3 percent annual demand for new construction. By 2023, over 40 million people will live in urban areas, requiring new buildings and accelerating energy demand[190]. There is a need to enforce the Energy Conservation Building Code (ECBC) in the building sector.

The improved building envelope efficiency can reduce the electricity demand for air conditioning by 20 percent[191]. One potential solution is to introduce energy-efficient measures in new construction using sustainable materials, technologies, and design strategies such as Building Information Modeling (BIM) (Box 1). In other words, implementing building codes in Pakistan's buildings is a promising path to reaching energy efficiency goals amidst the energy crisis.

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[189] https://neeca.gov.pk/SiteImage/Downloads/DRAFT%20NEEC%20ACTION%20PLAN%202023-2030.pdf

[190] https://neeca.gov.pk/SiteImage/Downloads/DRAFT%20NEEC%20ACTION%20PLAN%202023-2030.pdf

[191] Sustainable Energy Efficiency Program, ADB (2009)

Box 1: Building Information Modeling (BIM)

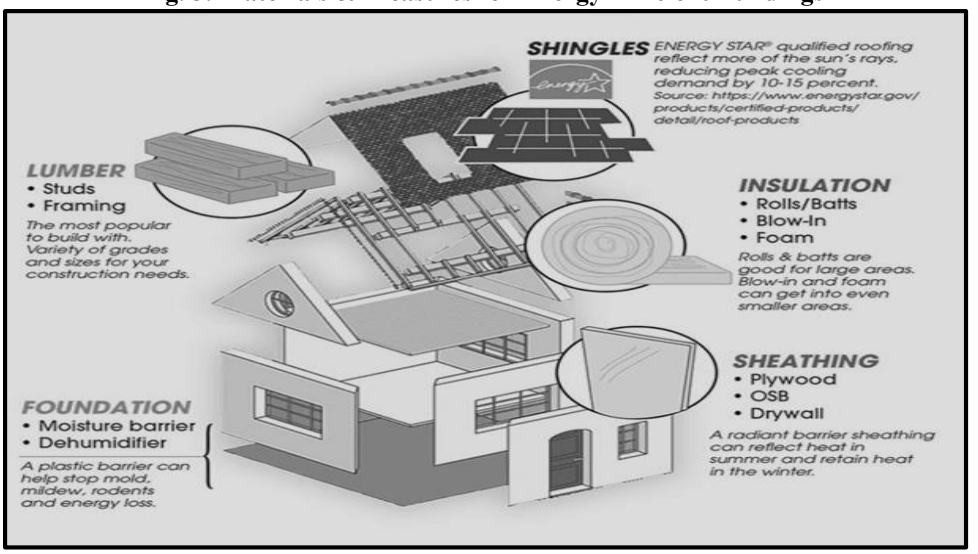
Building Information Modeling (BIM) can decrease the expenses of constructing energy-efficient structures. Using BIM software from companies like Autodesk (San Rafael, CA, USA), EnergyPlus (Orlando, FL, USA), EnergySoft (Novato, CA, USA), and Trimble (Sunnyvale, CA, USA) can help architects, engineers, and construction workers integrate suggestions for more convenient, reliable, and cost-efficient energy-efficient buildings. Combined with energy-efficient tools, BIM can perform a life-cycle cost analysis (LCCA) of a building over its lifetime.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has developed guides and codes that are now the industry standards for energy-efficient green buildings. The United States has also established programs such as Leadership in Energy and Environmental Design (LEED) to certify green buildings and verify their design.

Source: Abbas et al., 2022.

The energy efficiency of a building is determined by how its energy consumption per square meter of floor area compares to established energy consumption benchmarks (Abergel, 2020). Following the ECBC guidelines can help determine appropriate material usage (as shown in Figure 3) and appliance standards. Regulatory regimes, where present, can improve efficiency in building construction and appliances. To achieve energy efficiency, certain measures can be adopted for heating, cooling, air-conditioning, ventilation, lighting, fans, pumps and controls, office or other electrical equipment, and electricity consumption for external lighting, depending on the country and types of building. One potential measure to achieve energy-efficient buildings is to adopt Phase Change Material (PCM) in new buildings or make changes in the existing buildings by retrofitting (Abergel, 2020).

Fig. 3. Materials & Measures for Energy-Efficient Buildings



PROSPECTS OF ENERGY CONSERVATION BUILDING CODE (ECBC) IN PAKISTAN

Research indicates that BIM software can improve energy efficiency in smaller residential buildings to address Pakistan's energy crisis and environmental impact (Arif et al., 2021). Innovations in building design, energy-efficient materials, appliances and ECBC implementation can reduce energy burden.

Pakistan has a sunny and hot climate in most areas due to its geographical location. However, some regions experience extreme weather conditions, resulting in high energy demand for cooling, thus increasing energy consumption. Research shows that incorporating energy conservation measures (ECMs) can improve building energy efficiency, achieving a 40 percent increase in sustainability and cost-effectiveness and saving PKR 113K/year. An energy-efficient house can save up to 65 percent of the annual energy consumption by insulating building materials and solar panels. Though the initial investment cost increases by PKR 1.1 million, it saves PKR 76K/year (Shakoor et al., 2023). Long-run energy savings can offset the upfront incremental construction cost (Chen et al., 2013).

Smart buildings use various technologies to increase efficiency in design, construction, and operation for energy savings[192]. Similarly, Zero-energy buildings (ZEBs) use minimal external energy and have zero carbon emissions. They achieve this through on-site renewable energy sources (Figure 4). On-site renewable energy sources power them to meet energy requirements (Kylili, 2015). Energy-efficient buildings and intelligently designed zero-energy buildings (ZEBs) have the potential to create smarter cities through efficient energy management. Building envelopes alone can save up to 40 percent of the energy consumed by a building and implementing the ECBC can achieve up to half of the energy-saving potential.

There are two strategies[193] to make the existing buildings energy efficient. *Active strategies* consist of heating and cooling systems. *Passive strategies* include building orientation, envelope, air sealing, continuous insulation, daylighting, and natural ventilation opportunities. Passive strategies normally add much front cost and can even reduce the cost of active design strategies by reducing heating and cooling loads (Box 2).

Box 2. Five building Principles behind Passive Building

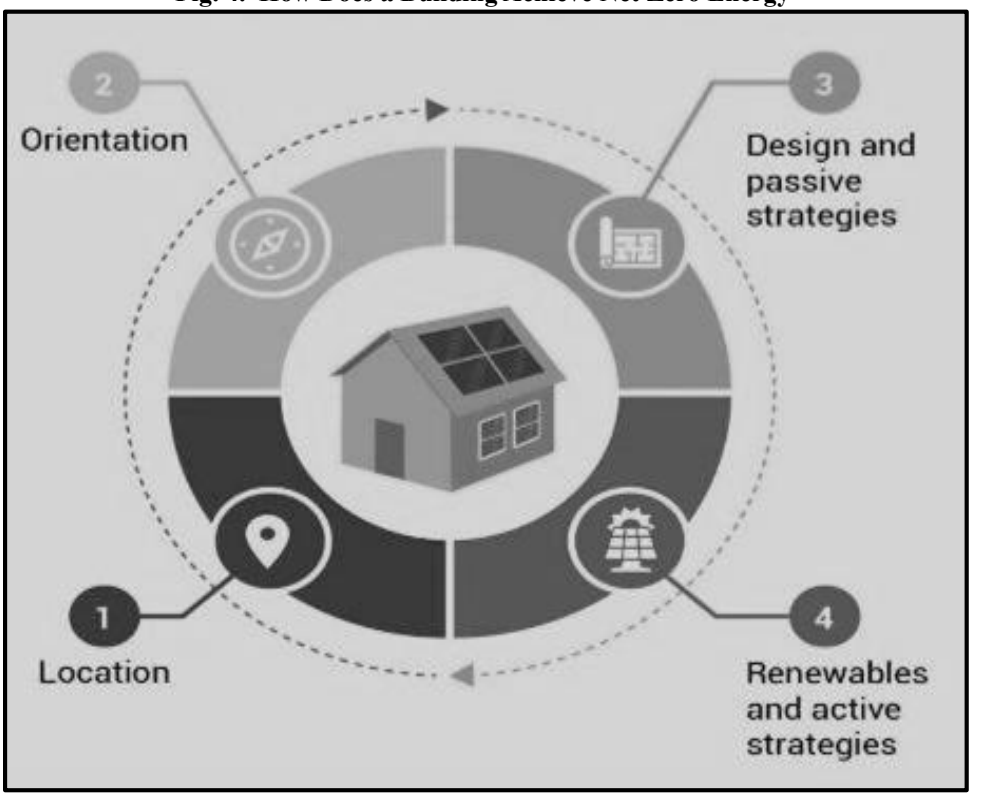
- Continuous insulation breaks thermal bridges between the inside and out,
- Airtight construction stops heat and moisture,
- Optimised windows keep heat in and out,
- Balanced ventilation ensures fresh air & controls moisture, and
- Minimal mechanical is all a super tight building need.

Source: https://commercial.phius.org/service-category/5-principles-drive-phius

[192] SMART2020: Enabling the low carbon economy in the information age," (The Climate Group.2008):3/41.

[193] https://commercial.phius.org/service-category/5-principles-drive-phius

Fig. 4. How Does a Building Achieve Net Zero Energy



Existing buildings can be made energy efficient by retrofitting. An energy audit suggests that the annual energy usage and annual energy cost can be reduced up to 2.33 percent & 4.54 percent respectively, by improving the window-to-wall ratio. Almost 7.62 percent of energy cost can be reduced by modifications in lighting fixtures. Changing the HVAC type can save an additional 14.8 percent of energy costs. Moreover, installing solar photovoltaic panels can save up to PKR 1 million, and natural ventilation can save more than PKR 0.2 million/annum & solar PV panels installation can save up to PKR 1 million annually (Arif et al., 2021). At the national level, NEECA has mandated compliance of ECBC for all new buildings by the end of 2024[194] to achieve energy efficiency targets in the building sector.

NATIONAL ENERGY EFFICIENCY & CONSERVATION AUTHORITY (NEECA)

NEECA, established under the Ministry of Energy (Power Division), is mandated to promote all energy conservation activities across different sectors of economy at the Federal level. It aims to improve energy intensity across sectors through cost-effective measures in cooperation with provincial authorities to achieve sustainable development (Box 3).

[194] https://neeca.gov.pk/SiteImage/Misc/files/NEEC%20Policy%202023-1.pdf

Box 3. NEECA's Initiatives to Ensure EE&C

- In new buildings, mandatory compliance of ECBC by the end of 2024.
- In old buildings, mandatory energy audits of designated consumers with five-year energy saving plan by 2025.
- Compliance with minimum energy performance standards (MEPS) & labelling regimes for electric & gas appliances, & equipment by July 2023.
- Issuance of guidelines by PPRA to ensure procurement of Pakistan energy label appliances in the country.
- Placement of energy managers at designated consumers of the building sector for verifiable energy management system deployment vis-à-vis regular reporting.
- Mandatory energy audits pre- and post-solarisation initiatives in the public buildings.
- The deployment of solar or other distributed energy resources in collaboration with Provincial Designated Agencies.

The energy efficiency potential of Pakistan is estimated to be around 15-20 percent of primary energy use[195]. Funneling the focus to building sector, the NEECA Policy 2023 aims to save 2.2 MTOE of energy with an emission reduction of 8.29 MTCo2 by 2030[196] by taking specific measures (Box 2). For instance, retrofitting existing residential buildings with EE&C measures can reduce final energy consumption by up to 22.2 percent and GHG emissions by 24.87 million tons.

Extant research supports the use of BIM and building performance simulation to investigate energy-efficient measures by analysing the effectiveness of various construction and material alternatives (Bughio et al., 2021). NEECA has approved the revised Energy Conservation Building Codes (ECBC) 2023 to improve energy efficiency in buildings.

ENERGY CONSERVATION BUILDING CODES (ECBC) 2023

ECBC 2023 sets minimum requirements for energy-efficient design and construction of new and renovated buildings, focusing on building envelope, equipment, and systems. The ECBC-2023 covers optimising building envelopes, passive building design, insulation, retrofitting existing buildings for energy efficiency, energy analysis monitoring devices, renewable and geothermal energy potential, and energy management systems.

With the annual rate of construction of new buildings in Pakistan reaching 5.3 percent, implementing ECBC during the early phases of construction can ensure energy efficiency by limiting heat loss/gain with effective building envelope techniques. Effective implementation of ECBC 2023 can reduce the overall energy demand of the building sector, saving millions in public funds. This code will encourage eco-friendly structures that produce fewer GHG emissions and possess resilient features for adapting to climate changes.

NEECA has drafted an action plan demonstrating that implementing EE&C measures in domestic and government buildings can save around 2.63 MTOE energy[197].

[195] https://www.adb.org/projects/42051-023/main#project-pds Access Date: August 02, 2023

[196] https://neeca.gov.pk/SiteImage/Misc/files/NEEC%20Policy%202023-1.pdf

[197] https://neeca.gov.pk/SiteImage/Downloads/DRAFT%20NEEC%20ACTION%20PLAN%202023-2030.pdf

Various measures will be taken to promote energy efficiency nationwide, including mandatory energy audits, appliance testing, and fiscal incentives. In terms of achieving its targets, NEECA's success in EE&C institutionalisation has been acknowledged internationally. Pakistan scored 36 in 2021 compared to 28 in 2019 on the Regulatory Indicators for Sustainable Energy (RISE) metric developed periodically by the World Bank[198]. For example, in Financing Mechanisms for Efficiency, Building Energy Codes, Energy Labelling Systems, and Minimum Energy Efficiency Performance Standards, Pakistan has demonstrated improvement from 0, 10, 0, and 22 to 8, 25, 13, and 32 respectively.

Table 1

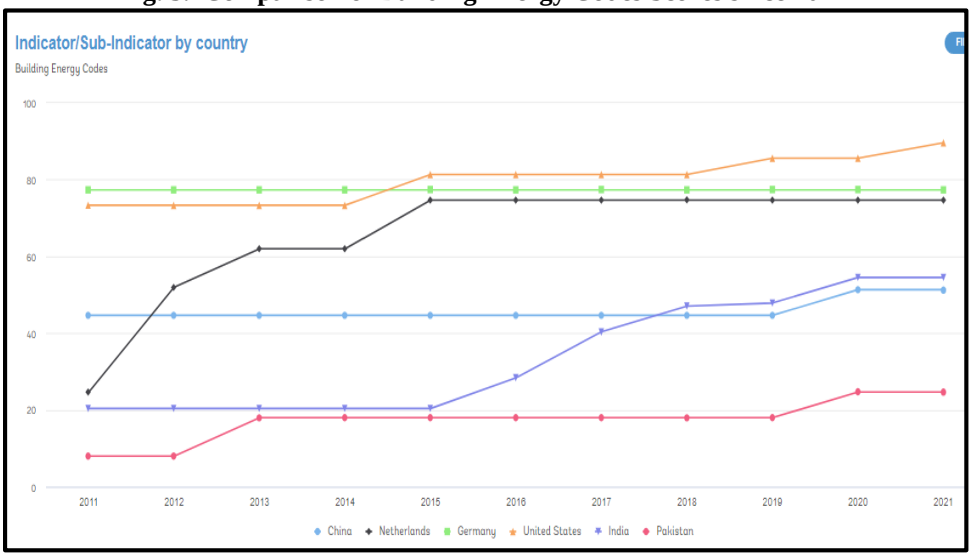
Comparison of Countries in Terms of Scores of Sub-Indicators of Building Energy Codes RISE

Sub-Indicators	USA	Germany	Netherland	China	India	Pakistan
New residential & commercial buildings	88	60	80	60	76	40
Compliance system	100	100	66.87	33.33	53.33	4.93
Renovated buildings	100	100	100	50	40	50
Building energy information	100	66.67	66.67	33.33	53.33	33.33
Green Buildings	60	60	60	80	50	4.93

Source: World Bank.

Despite improved Building Energy Codes since 2012 (Figure 5), Pakistan's compliance system and Green Buildings concept still lag behind many (Table 1). Developing a sustainable culture is vital to reducing energy consumption and carbon emissions.

Fig. 5. Comparison of Building Energy Codes Scores since 2012



Source: https://rise.esmap.org/analytics.

[198] www.esmap.rise.org

KEY TAKEAWAYS

The building sector accounts for one-third of total energy consumption (IEA, 2013). Pakistan has one of the highest domestic energy consumption rates. Effective EE&C measures can save up to 2.63 MTOE in Pakistan's building sector, but implementing them requires proper national, provincial, and local institutional setup. This can help address Pakistan's energy crisis and environmental impacts.

The government should facilitate, making it easier for buildings to be retrofitted for energy efficiency. Creating an energy conservation culture is essential to raise awareness through social and electronic media. Regular audits should be conducted for existing buildings; new ones should be required to obtain a compliance certificate. This can be achieved by implementing ECBC.

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