

# A DECADE-AND-A-HALF OF RESEARCH ON BUILDING ENERGY PERFORMANCE CERTIFICATION: A SYSTEMATIC REVIEW

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## ABSTRACT

*Certifying the energy performance of buildings is a crucial step towards global sustainability. This study systematically reviews the literature on Energy Performance Certification (EPC) schemes to identify the key themes in EPC research over 15 years. The aim was to unearth the best practices of certification schemes and to identify what challenges confronted attempts at implementation. The Scopus electronic database was searched for articles on EPC schemes published between 2005 and 2020 (both years inclusive). Out of the large body of literature retrieved, 67 publications, comprising journal articles, conference proceedings, and technical reports, were selected for analysis after the abstracts and contents were systematically perused. The findings revealed that more than 68% of the publications reviewed originated from Europe, lending credibility to European countries being labelled as leaders in EPC scheme implementation. It was further unveiled that the key themes from previous research works included the importance of EPCs, the impact of EPC on the market value of buildings and the limitations of EPCs. This review has revealed the importance of promoting EPC for energy efficiency from the existing building stock. The authors thus recommend adopting the identified best practices underlying successful EPC schemes to promote energy efficiency in existing buildings in Ghana.*

**Keywords:** Energy efficiency, Energy performance certificates, EPC schemes, Systematic literature review

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## INTRODUCTION

Globally, the increasing energy demand due to the effects of climate change, coupled with the dwindling sources of supply of fossil fuels (Sassi, 2006; Kemausour *et al.*, 2011) has prompted widespread actions toward enhancing energy efficiency from the building sector. Climate change challenges have further saddled designers of buildings with the burden of creating energy-efficient structures that promote comfortable and healthy indoor environments. Consequently, evaluating the energy performance of buildings in use for possible retrofitting has become an area of utmost interest to major stakeholders in the building design and construction industry.

This evaluation is key to determining the efficiency of energy usage in buildings to improve their environmental impact. Accordingly, various energy performance rating schemes for buildings have been developed in many countries worldwide. Within the European Union (EU), the Energy Performance of Buildings Directive (EPBD) has driven the agenda for the member states to prioritise a more transparent energy performance of both old and new buildings (Volt *et al.*, 2020). A certificate is mandated to be issued for buildings under construction, for sale, or rent (The Buildings Performance Institute, Europe [TBPIE], 2010).

This certificate is considered vital in the steps towards reducing the energy consumption of buildings (Norvaisiene *et al.*, 2014). It presents information on the building's energy performance on a rating scale from most efficient to least efficient, which could either be alphabetical or a sliding scale combined with colours (TBPIE, 2010). The data on the certificates offer prospects for future energy policies, monitoring of building energy performance, and energy efficiency market research (Arcipowska *et al.*, 2014;

Pasichnyi *et al.*, 2019). Empirical evidence in the literature indicates that EPC schemes have helped with energy management from the building sector (Nikolaou *et al.*, 2009; TBPIE, 2010; International Energy Agency [IEA], 2010; Bordier *et al.*, 2018; Oates *et al.*, 2020; Volt *et al.*, 2020).

However, in Ghana, there are no EPC schemes for buildings (Iwaro and Mwashha, 2010; Gyimah and Addo-Yobo, 2014; ECOWAS Centre for Renewable Energy and Energy Efficiency [ECREEE], 2015; Ministry of Power, 2015; Osei-Poku *et al.*, 2023). Instead, there are energy ratings for some of the electrical appliances used within buildings as part of efforts to reduce energy consumption from the building sector (Andoh, 2020). The Energy Commission of Ghana reports increased energy conservation from the building sector through compliance with these appliance rating regulations (Energy Commission, 2019).

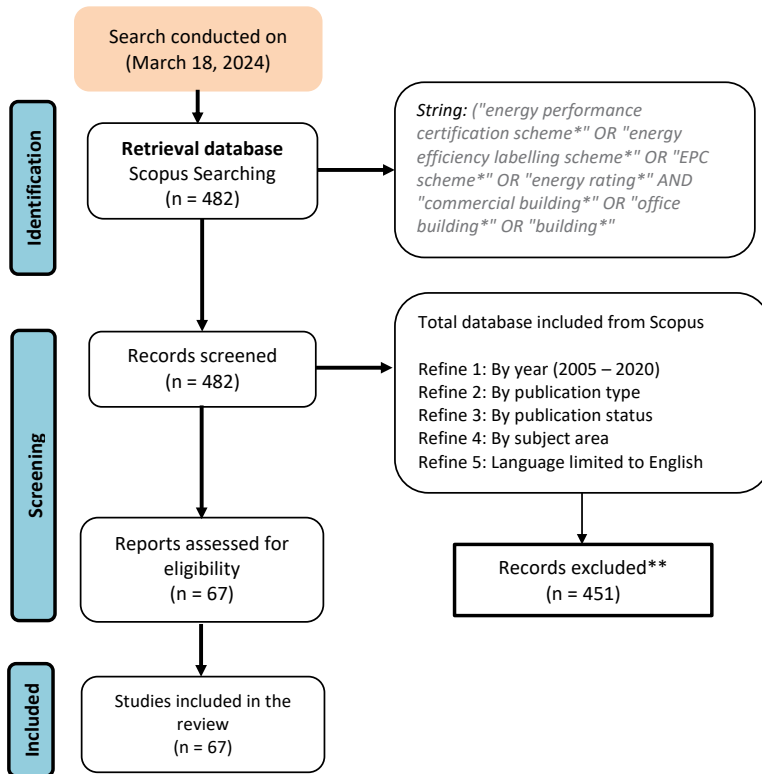
Frequent feedback from countries implementing EPC schemes has unveiled gaps and proposed remedies for large-scale adoption of such systems. According to Heijmans and Loncour (2019), continuous research has helped with modifications to promote increased public patronage. It is thus imperative for extensive research to be undertaken to serve as a guide for Ghana toward the successful implementation of a scheme that aims to promote energy efficiency from the existing building stock, according to Ghana's Minister of Energy (The BFT Online, 2022). This study analyses EPC research conducted between 2005 and 2020 (both years inclusive), exploring the thematic areas. The aim was to examine the foci and main conclusions of prior works to identify the best practices and the challenges of implementing EPC schemes. A study of this nature seeks to identify research gaps to serve as a foundation upon which future studies on the adoption and implementation of EPC

schemes in sub-Saharan Africa (SSA) could be conducted, using Ghana as a case study.

## METHODOLOGY

This research adopted a qualitative approach involving a Systematic Literature Review (SLR). Reviewing existing literature is fundamental in furthering knowledge and

facilitating theory according to Groat and Wang (2013). However, conducting an SLR is advantageous due to the extensive and replicable methodology used to identify, analyse, and synthesise the relevant data on a given subject (Siddaway *et al.*, 2019). The SLR involved identifying academic publications, screening, and selecting papers, as illustrated by the Prisma 2020 flow diagram in Figure 1.



**Figure 1:** Article Identification and Selection Procedure

### Selecting Academic Publications

The main data sources were academic journal papers, conference proceedings, and technical reports retrieved from the Scopus electronic database. Omrany *et al.* (2022) identify the selection of the right database as crucial for conducting scientific reviews, as it directly impacts the quality of the results. Thus, the Scopus database was

chosen because it hosts the largest number of multidisciplinary publications, facilitating searches across different sources. Search keywords and phrases were identified from a prior scoping review in sourcing the relevant literature. The retrieval search string was entered in March 2024 by combining the keywords with Boolean operators, as shown below:

TITLE-ABS-KEY (“energy performance certification scheme\*” OR “energy efficiency labelling scheme\*” OR “EPC scheme\*” OR “energy rating\*” AND “commercial building\*” OR “office building\*” OR “building\*”

The initial results yielded 482 documents. Guided by the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) framework, the search was limited to articles published from 2005 to 2020. The basis for selecting the time frame was to capture the trends in EPC research following the deadline for implementing the EPBD within EU member states. This screening action resulted in 261 papers. The document source was limited to journal articles, conference proceedings, and technical reports, resulting in 233 documents. Thus, academic theses, book chapters, editorials, and unidentified documents were excluded. The search was then limited by publication status, thereby excluding manuscripts categorised under “accepted manuscript”, “pending publication”, and “in press” from the selection. This yielded 176 documents. Furthermore, only articles published in the English language in the subject areas of Engineering and Energy were included in the final stage. With these filters, 67 documents were selected as the final representative sample to be reviewed for this write-up.

For categorisation purposes, the type of document, source title, year of publication,

and country of origin were noted for each paper studied. Additionally, the problems, aims, key findings, and major conclusions of the papers were tabulated in MS Excel to facilitate the analysis. Finally, the findings and conclusions of each paper were analysed for their contribution to EPC research over the period under study.

## RESULTS AND DISCUSSION

It must be emphasised that the analysis is based solely on the data retrieved from the specific sampling approach adopted and, thus, does not represent an exhaustive review of a complete population of papers published on the subject matter, which would be impractical.

### Distribution of EPC research reviewed

As per the selection process described in the Methodology, the literature search yielded 67 publications for analysis. Of these, 41 were journal articles, 14 were conference papers, and 12 were technical reports. The journal from which the highest number of papers was considered was Energy Policy (9). Elsevier publishers had the greatest number of publications in this review (24), followed by Taylor and Francis (6). Details of the distribution of the papers according to sources and journal publishers are presented in Table 1.

**Table 1: Distribution of papers according to sources and journal publishers**

Distribution of papers according to sources		
Source	No. of publications	Percentage of total (%)
Journals	41	17.50
Conference proceedings	14	15.00
Reports	12	7.50
<b>Total</b>	<b>67</b>	<b>100</b>

**Distribution of journals according to publishers**

<b>Publisher</b>	<b>No. of papers</b>	<b>Percentage of total (%)</b>
Elsevier	24	58.53
Taylor and Francis	6	14.63
Emerald	3	7.32
MDPI	2	4.88
Wiley- Blackwell	2	4.88
Rizvi College of Arts, Science and Commerce	2	4.88
ARNP	1	2.44
Frontiers Media S.A.	1	2.44
<b>Total</b>	<b>41</b>	<b>100</b>

The majority of papers were from European countries as indicated in Table 2, lending credibility to European countries being labelled as leaders in EPC scheme

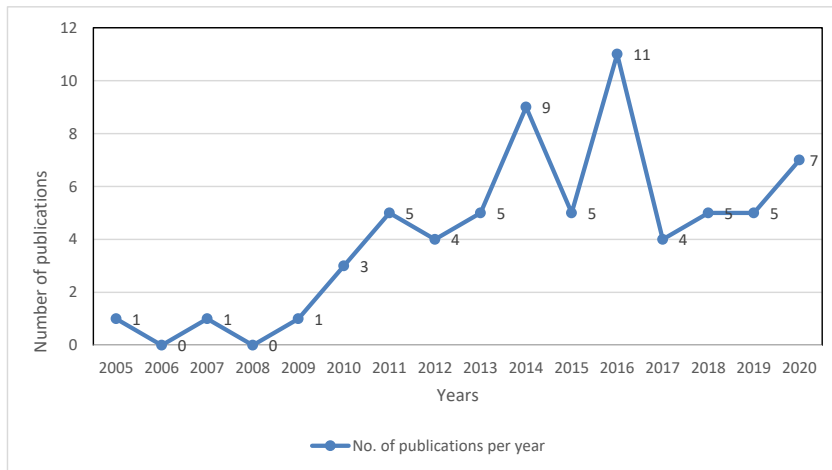
implementation by Janda (2008). This result could be attributed to the mandatory use of EPCs in the EU from 2006 (TBPIE, 2010).

**Table 2: Number of publications per continent**

<b>Continent</b>	<b>No. of publications</b>	<b>Percentage of total (%)</b>
Europe	46	68.65
Asia	12	17.91
Africa	4	5.97
North America	3	4.48
South America	2	2.99
<b>Total</b>	<b>67</b>	<b>100</b>

Furthermore, the yearly frequencies of the papers reviewed showed a steady increase in the number of research publications on EPC. Illustrated in Figure 1 are the number of publications per year for the period under review. It must be noted that at the initial stages of EPC implementation, there was a need for EU member states to gather enough

experience as elucidated by the BPIE report (TBPIE, 2010). Therefore, there are fewer publications from the earlier years (from 2005 to 2010) as compared to the latter part of the period under review (from 2011 to 2020) with more feedback through constant research from the EU. The year 2016 recorded the highest number of publications (11).



**Figure 2:** Number of publications per year

## Key Concepts and Themes in EPC Research

The publications were perused to identify stated problems, major research aims, objectives, and conclusions. This helped in classifying the publications under some themes as presented in the subsequent discussion.

### *Gaps in building energy performance*

This is one of the most popular areas of building energy performance schemes that several researchers have explored. Many examples in the literature support the claims that buildings fail to achieve the predicted energy savings when put to actual use. This could imply that the buildings are not being operated by users as designed or are not performing as expected. Also, research has established that there is usually a gap between the results of calculated ratings and operational ratings (Panayiotou *et al.*, 2010; Drousta *et al.*, 2020). The differences have been attributed to several causes, among which are the use of assumptions in some factors such as climatic conditions, occupancy, and equipment when simulating the energy

performance of buildings (Majumdar, 2014; van Dronkelaar *et al.*, 2016). Other causative factors are specification uncertainty in modelling occupant behaviour, poor operational practices, and malfunctioning equipment (van Dronkelaar *et al.*, 2016; Liang *et al.*, 2018; Cozza *et al.*, 2020). The research of Burke *et al.* (2005) revealed that using default figures and/ or assessors' discretion for some input parameters during simulation had significant consequences on the energy performance grading of buildings. Such a failure to accurately forecast energy performance at the design stage could lead to increased energy costs during use, as postulated by Cozza *et al.* (2020). Furthermore, if the high impact of occupancy on energy consumption is not considered when calculating building energy use, the resultant gap between estimated and actual consumption by existing buildings would mean the buildings would not have the correct classification (Harputlugil, 2018). Operating a building comes with social, economic, and environmental issues. It is therefore not surprising that the energy performance gap exists as in some instances, actual energy usage may be less than

estimated (Cozza *et al.*, 2020; Drousta *et al.*, 2020) or vice versa. The gap could lead to buildings being inaccurately classified based on their estimated values.

To reduce the energy performance gap, it is best to incorporate the energy performance assessment during the design process, using the certification as a decision-supporting tool for new designs, as suggested by Cozza *et al.* (2020). In the case of existing buildings, van Dronkelaar *et al.* (2016) recommend accessing energy data to monitor and analyse the operational building performance as part of measures to reduce the gaps. Furthermore, it is suggested that assessors should spend more time thoroughly examining buildings and collecting more real empirical data before preparing the EPCs (Cozza *et al.*, 2020; Drousta *et al.*, 2020). These steps can help to get realistic estimates based on the actual energy use of the buildings. However, the challenge is that such a detailed energy audit would be time-consuming and expensive. This calls for cost-effective and innovative EPC schemes to deliver best practices within budgetary constraints.

### **Importance of EPCs**

Literature has shown that energy performance certification of buildings and the certificates issued are useful to several stakeholders in the building construction industry, including property owners, buyers, tenants, real estate moguls, and policymakers (IEA, 2010; Anagnostopoulos *et al.*, 2015). The energy label conveys vital information about a building's energy performance, especially regarding energy savings. In this sense, numerous literary sources have revealed that a higher EPC rating increases the worth of buildings and consequently influences the decision of buyers and renters (for example, IEA, 2010; Fuerst and McAllister, 2011a; Fuerst *et al.*, 2012; Bio Intelligence Service, 2013; Charalambides *et al.*, 2018; Li *et al.*, 2019; Cozza *et al.*, 2020; Khazal and Sønstebo, 2020). Additionally, the building energy ratings were identified to be pivotal in decisions to renovate buildings in the conclusion of Charalambides *et al.* (2018). Furthermore, the information on the certificates could guide the occupants to adopt more energy-saving measures to enhance the energy performance of the buildings (Adam *et al.*, 2016; van Middelkoop *et al.*, 2017). Additionally, EPCs have been identified to have a positive impact on occupant satisfaction with buildings (Parkinson *et al.*, 2013). The data from EPC databases in several countries have been applied in further energy efficiency-related research such as by Costanzo *et al.* (2016), López-González *et al.* (2016), Hjortling *et al.* (2017), Pasichnyi *et al.* (2019), and Drousta *et al.* (2020).

The information on the certificates guides prospective owners and tenants in imagining the energy efficiency potential of different buildings (newly built or existing) and helps them make informed comparative analyses before transactions are sealed. In the case of existing buildings, the recommendations on the certificates provide a means for these buildings not to fall short of the requirements of newer building codes, as many were constructed before major global attention was focused on energy efficiency. Feedback from several evaluations throughout implementation has provided the opportunity to gather details to enhance newer building codes and guided decisions to amend the EPC directives over the years. The updated directives have led EU member states to improve the certificates for better public patronage. Several enhancements have consequently been made to the contents of the certificates. According to Heijmans and Loncour (2019), some countries, such as Denmark and Norway, have revised the limits of the class labels; others (e.g., Italy) have created a more user-friendly interface on

the certificates. In other countries, including Estonia and Lithuania, the original 7-band alphabetical scale has been modified to include more classes (Heijmans and Loncour, 2019; Jonkutė *et al.*, 2020).

### ***Impact of energy labels on the market value of buildings***

Another leading research theme identified was the relationship between the energy performance class and buildings' market values, with discussions in 14 of the reviewed articles on this particular theme. Several studies have revealed dissimilar results on the impact of EPC on property values when rented or sold. Cerin *et al.* (2014) attributed such variations to the age and sale-price class of buildings. For instance, evidence from Germany, the UK, and Norway revealed no strong relationships between energy labels of buildings and the sale/ rental transaction values (Amecke, 2011; 2012; Fuerst and McAllister, 2011a; Olaussen *et al.*, 2017; 2019). On the contrary, Hyland *et al.* (2013) discovered a positive correlation with a stronger effect on selling prices when they studied the impact of energy efficiency ratings on the sale and rental prices of buildings in Ireland. The report from the Bio Intelligence Service (2013) also indicated increased price premiums of properties with higher EPC ratings from some European countries. It was likewise revealed by Ankamah-Yeboah and Rehdanz (2014) that energy efficiency labels positively correlated with better sale prices of buildings, observing that non-residential buildings commanded a higher premium in this regard. The study of Khazal and Sønstebo (2020) also concluded a significant effect between the class of EPC and the rental values of buildings in the residential market of Norway. The authors further established that, irrespective of energy efficiency, houses with energy labels attracted premium rents compared to those without labels. Similarly, it was discovered that higher rental values

were charged for non-residential buildings in the UK with better energy ratings (Fuerst and McAllister, 2011a; Fuerst *et al.*, 2012). Buttressing evidence from other countries worldwide, including Australia and the US, further attests that certified energy-efficient buildings command higher rental or selling premiums (Das *et al.*, 2011; Fuerst and McAllister, 2011b; Freybote *et al.*, 2015). The conclusions from all these studies provide ample empirical evidence to support that a better energy class label results in payment of higher amounts to rent or buy that particular property. Perhaps it is because a higher-class label indicates better energy efficiency, which offers good returns on investment.

### ***EPC schemes – approaches and methods***

There are several methods and frameworks used to assess the energy performance of buildings as part of the global pursuit for sustainability to mitigate the environmental, economic, and social impacts of buildings. Such EPC frameworks are applied to evaluate both new designs and existing buildings. The EPBD allowed different countries to propose methodologies best suited to their local contexts due to the varied factors influencing energy use in each country. Among the considerations made during the development of effective EPC schemes were the accuracy and comprehensiveness of the method as well as the reproducibility of results (Fowler and Rauch, 2006; TBPIE, 2010; Kelly *et al.*, 2012; Harputlugil, 2018). The developed methodologies were validated by comparing them to already established standards (as was done by Alyami and Rezgui, 2012; Banani *et al.*, 2016) or by assessing case study buildings, such as was undertaken by Gyimah and Addo-Yobo (2014). Some schools of thought argue that the varying methodologies serve as a limitation of EPC schemes. However, the cultural, climatic, and capability differences ensure that the unique factors influencing energy performance

for each country are considered in rating its buildings. To ensure data quality for standardised comparison across countries, EPC results are collected and stored in national repositories. Adopting this national approach in developing methodologies and cataloguing results has the advantage of a wealth of data with vast opportunities to exploit in further energy studies (Pasicnyi *et al.*, 2019). For example, the study of Nikolaou *et al.* (2009) depended on a national database as a credible and valuable source to assist in developing relevant benchmarks to guide the certification of office buildings in Greece.

### **Limitations of EPC schemes**

Many previous studies revealed that several limitations had been reported in countries since the inception of EPC implementation. Among the concerns raised are issues of the quality, credibility, validity, and usability of the EPC data (Amecke, 2011; 2012; Arcipowska *et al.*, 2014; Harputlugil, 2018; Cozza *et al.*, 2020; Volt *et al.*, 2020). Other limitations reported were different schemes with no conversion standards (Brøgger and Wittchen, 2016) and varying methodologies for calculation and certification (Harputlugil, 2018; Sürmeli-Anac and Hermelink, 2018). It has been argued that the variations in calculation methods result in a situation where making effective comparisons of buildings based on class labels becomes difficult, especially in countries where there have been updates to the class labels.

Some researchers have also described the energy performance assessments for new designs as restricted since they depend solely on simulations and not the actual energy use. The authors Burke *et al.* (2005), Pagliaro *et al.* (2015), Visscher *et al.* (2016), Harputlugil (2018) and Cozza *et al.* (2020) have all argued that such predictions were limited as post-design changes in building operations and management, the effect of occupants

and climatic variations as well as the impact of buildings on the environment may not be accurately considered and modelled. In addition, Harputlugil (2018) revealed other limitations of the EPC regarding its use of what is described as 'static data', which could neither be updated nor used for real-time data management. Also, the interaction between buildings is not considered when calculating the energy performance of each building (Harputlugil, 2018).

Another limitation that has been brought to the fore relating to quality assurance is how the experts assessed and certified the buildings. Burke *et al.* (2005) revealed that using assessors' discretion during dynamic simulation resulted in significant variations in the energy performance ratings of buildings. Energy certification experts play a pivotal role in ensuring that EPCs are credible (TBPIE, 2015). Thus, the trustworthiness of the assessors who evaluate the energy performance of buildings, rate them, and prepare the EPCs has been questioned in some of the papers reviewed. Amid the questions arising are 'who qualifies as an energy certifier?', 'what level of training and competencies does the certifier require?', 'Should the training be one-off or a continuous event?' (Arcipowska *et al.*, 2014; TBPIE, 2015; Cozza *et al.*, 2020). Ensuring quality is largely dependent on the assessor, thus, the competence of certifiers is considered a critical issue. In this regard, well-developed training schemes that define the minimum standards for academic qualification, professional experience, and licensing procedures are employed to ensure data quality (TBPIE, 2015; Harputlugil, 2018; Li *et al.*, 2019; Cozza *et al.*, 2020; Volt *et al.*, 2020). Assessors and certifiers require a mandatory examination before licensure by a competent public authority and periodic renewal of licenses as measures to monitor and control their activities (TBPIE, 2015). Furthermore, Cozza *et al.* (2020) recommended updating

training materials for the certifiers with structures in place for the periodic renewal of expert accreditation combined with more demanding examinations. Additionally, it is suggested that assessors be trained through further compulsory follow-up courses and workshops to keep them abreast with global trends (Cozza *et al.*, 2020).

### **Barriers to the implementation of EPC schemes**

The barriers that have impeded the smooth implementation of EPC schemes, as unveiled from the papers reviewed, included financial, bureaucratic, political, and attitudinal barriers. The cost element involved in acquiring an energy performance certificate was identified to be the main barrier deterring public patronage of EPC schemes (TBPIE, 2010; Addy *et al.*, 2014; Yu *et al.*, 2019). Certificate cost is determined by the quantum of work performed by the assessor. Among the factors influencing the expert's charges are the building design (size and complexity), input data, and methodology for calculation and assessment. The more experimentally determined variables incorporated in the calculation, the more expensive the certificate becomes (Burke *et al.*, 2005). However, when a certificate had a lower price, it was often linked to a lower quality assessment, which was less valued by the public (TBPIE, 2010).

Some people also considered acquiring a certificate a waste of money, arguing that the information provided on it was not specific to their needs (Amecke, 2011; Wagner, 2014). This resulted in stakeholder apathy

towards the EPC process. To encourage patronage, building owners, managers, and occupants must be made aware of the financial obligations involved in the certification process so they can make well-informed choices and compromises where necessary. Again, all the building industry players, from designers to users, must coordinate and synchronise their efforts to ensure the energy efficiency of a building. To this end, Bull *et al.* (2014) recommended better stakeholder collaborations during the certification process.

Additionally, slow administrative and bureaucratic procedures presented challenges to EPC scheme implementation in some countries (TBPIE, 2010; Olausen *et al.*, 2017). Another identified barrier is the enforcement of compliance. It has been acknowledged that non-compliance with regulations (in countries where such exist) is another challenge that impedes the execution of building energy performance certification schemes (TBPIE, 2010; Cozza *et al.*, 2020). Furthermore, despite the success stories, the IEA (2010) revealed that building owners and occupants were not under an obligation to implement the suggested remedial actions on the certificates. This presents a challenge in achieving national and regional goals towards energy efficiency from the existing building stock. It is recommended, therefore, that proper monitoring and evaluation (M and E) should be ensured to enhance the enforcement of energy-saving recommendations provided on the certificates. A summary of the barriers is presented in Table 3.

**Table 3: Barriers and Challenges to Adopting and Implementing EPC Schemes**

<b>Barrier</b>	<b>Sources</b>
High cost of certification process	Burke (2005); TBPIE (2010); Addy <i>et. al.</i> (2014); Yu <i>et. al.</i> (2019)
Generality of information on certificate	Amecke (2011); Wagner (2014)
Bureaucracy/ Slow administrative procedures	TBPIE (2010); Olausson <i>et. al.</i> (2017)
Non-compliance to regulations	TBPIE (2010); Cozza <i>et. al.</i> (2020)
Lack of qualified assessors/ certifiers	Arcipowska <i>et. al.</i> (2014); TBPIE (2015)
Lack of legal obligation to display certificate/ implement recommendations	IEA (2010); Amecke (2011)

**Inferences from the Review**

The foregoing findings on the key themes of EPC research from 2005 to 2020 have provided insights into the main concepts and best approaches to guide the adoption and implementation of EPC schemes for Ghana. Accordingly, a summary of the optimal practices has been provided as follows:

***Developing indigenous methodology***

It was discovered that the EU directive allowed member states to develop approaches best suited to their local contexts, as a one-size-fits-all approach was not feasible. This has helped with the success of implementation as there are climatic, cultural, and capability differences among countries. The development of indigenous methodologies ensured that the unique factors influencing energy use in each country were not excluded. The adoption of a national approach involving multiple stakeholders allows data to be collected and stored in central electronic registers, providing a wealth of data for vast opportunities to exploit in energy studies affecting policy and practice, as recommended by Pasichnyi *et al.* (2019). Such a national catalogue serves as a source of credible and valuable information on the

EPC implementation to assist in developing the relevant benchmarks to guide the rating and certification of buildings (Nikolaou *et al.*, 2009; TBPIE, 2010).

***Setting realistic and specific validity periods***

Having a specified time frame within which the information on the certificate is valid has helped with the success of EPC implementation. The renewals are necessary due to variations in energy use, arising sometimes from changes in occupancy and use of the building. Regular reassessments for periodic certification help reveal accurate and current data on a structure’s performance. This information, when compared over time, would expose whether recommended inputs are ideal or otherwise if implemented. The reassessment and issuance of a new certificate in the event of a change in occupancy is also an excellent practice to adopt as it offers an effective comparative assessment of the performance of a building over a period.

***Engaging stakeholders regularly***

The involvement of stakeholders in the building design and construction industry, as well as owners and occupants of

buildings, helped with the success of EPC schemes. In some countries, there were widespread promotional campaigns in the form of advertisements to raise awareness among stakeholders and the general public. Feedback through constant research helped to enhance the EPC schemes within the EU member states. This has enabled policymakers to incorporate the necessary up-to-date measures to promote public patronage in countries such as Denmark, Italy and Norway, as averred by Heijmans and Loncour (2019) and Jonkutè *et al.* (2020). Additionally, providing regular feedback on EPC implementation status by the agencies in charge increases public education and awareness, thereby promoting acceptance.

## CONCLUSION

This study undertook a systematic review of energy performance certification research using the PRISMA checklist. It discusses the dynamic themes of EPC research between 2005 and 2020, indicating the main research directions. From these themes, it has been revealed that the extensive exploration of the schemes has helped in the significant improvement of the EPC implementation in countries that have adopted building energy labels. The foregoing literature also reveals some best practices and challenges relating to EPC schemes globally. Among the practices worth emulating are ensuring data quality through adopting a robust national methodology, and employing well-trained and licensed assessors for the certification process. This would improve consistency and ensure the credibility of the data presented on the certificates. Additionally, constant research should be undertaken to improve the process and product of the certification scheme. Some barriers of EPC scheme implementation that need to be thoroughly addressed include the high cost of certification which did not encourage public patronage,

and the bureaucratic process that slowed down the process of acquiring a certificate.

## RECOMMENDATIONS

This review has revealed the importance of promoting EPC for energy efficiency in existing buildings. It is recommended, therefore, that the best practices of current schemes be adopted in Ghana to improve the energy efficiency in the existing building stock. To fully examine EPC schemes, further research is suggested for an in-depth examination of the barriers inhibiting the implementation to understand why such exist. Additionally, future studies should explore the methods for data collection and analysis in building energy performance certification research.

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