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Review

Customer engagement strategies in retail electricity markets: A comprehensive and comparative review

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ABSTRACT

Retail electricity markets require development to ensure efficient and equitable pass through of wholesale electricity costs to customers. Customer engagement has been heralded as a concept to improve the wholesale-to-retail link, better harness flexible demand loads and co-ordinate distributed renewable generation and storage. This study reviews the state-of-the-art customer engagement trends in retail electricity markets, and in doing so, it first establishes a definition of customer engagement in the context of retail electricity markets. Second, the paper identifies that literature on customer engagement revolves around three key strategic themes, namely 'Customer Focus', 'Tariff Design' and 'Innovation'. Third, the paper systematically provides a comprehensive review of these customer engagement strategies in retail electricity markets. Finally, the study identifies the technical, market and social requirements to deliver an innovative retail electricity market structure to decarbonise society. This paper's crucial and novel policy recommendation is that integrating market mechanisms and technology (i.e. cross-linking across the three customer engagement strategy themes) is required to ensure robust and efficient retail electricity market operation as society advances to a net zero economy. The study concludes with the establishment of eight future research directions of customer engagement for retail electricity market design.

1. Introduction

Worldwide, governments have released new objectives to decarbonise society, combat global warming and protect our environment. This is exemplified by the United Nations '2030 Agenda for Sustainable Development' [1], the United States of America (USA) rejoining the Paris Agreement in early 2021 [2] and the net zero by 2050 emissions targets discussed at COP21 in Glasgow. There is consensus that the electrification of heating and transport energy demand is key to net zero [3,4]. However, other pathways are being explored to balance our excess greenhouse gas emissions (i.e., carbon capture utilisation and storage or the implementation of the circular economy concept). Some research studies have proposed 100% renewable energy systems, such as Hansen et al. [5], Jacobson [6,7], but how will energy system stakeholders and policy makers achieve this?

This decarbonisation pathway can only be achieved by changing how electricity markets operate and the deployment of renewable technologies such as rooftop solar photovoltaic (PV) panels, heat pumps [8], electric vehicles (EVs) [9], better grid balancing across local, national and transboundary levels, innovative ancillary services [10,11], demand response (DR) with smart meters [12] and increased levels of storage [13]. More recently, other studies have indicated that green hydrogen [14] and nuclear energy [15,16] also have an extensive role to play in the decarbonisation roadmap, as discussed in the Glasgow Climate Pact [17], in the drive to keep the global temperature rise well below 2 °C as per the Paris Agreement [18]. However, wholesale and retail electricity markets have a critical function in this transition [19], with this review study postulating that, in regions where retail competition is enabled, retail electricity markets need to be further integrated and better harmonised with wholesale electricity markets. Such market harmonisation will likely give rise to effective pass-through of generation and market costs to the consumer and encourage efficient and flexible electricity consumption [20]. Thus, a key factor in achieving

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Nomenclature

CMA	Competition and Markets Authority
CRU	Commission for Regulation of Utilities
DER	distributed energy resource
DR	demand response
ERCOT	Electric Reliability Council of Texas
EU	European Union
EV	electric vehicle
FPEER	Fuel Poverty Energy Efficiency Rating
GB	Great Britain
ICT	information and communications technology
IoE	Internet of Energy
Ofgem	Office of Gas and Electricity Markets
P2P	peer-to-peer
PHEV	plug-in hybrid electric vehicle
PV	photovoltaic
SVT	Standard Variable Tariff
TOU	time of use
UK	United Kingdom
USA	United States of America

such harmonisation is the promotion of active consumer participation with innovative communication technologies, distributed energy resources and the adoption of dynamic pricing, and with the interlinking of these elements through the retail electricity market [21–23].

If better market harmonisation is implemented effectively, it is anticipated that society will benefit from improved energy efficiency and reduced greenhouse gas emissions [24]. Active consumers will also support system reliability and security by adopting innovative engagement strategies such as DR, peer-to-peer (P2P) trading and making informed choices regarding electricity supplier and tariff selection [25]. Smart meter adoption is key to enabling the implementation of such strategies. However, there are perceived and actual data privacy and cybersecurity concerns that need to be alleviated. Véliz et al. [26] highlight that energy is somewhat intangible and abstract, so it is challenging for energy consumers to appreciate what the data reveals about them. So how will retail electricity suppliers encourage customers to reduce their carbon footprint and adopt smart meters? This is an important research question to be urgently addressed, considering net zero by 2050 targets.

Enhanced customer engagement is needed to advance retail electricity markets in regions that permit retail competition. The origin of this engagement behaviour emerges from the liberalisation of retail electricity markets, which led to thriving retail competition. With the increasing awareness of global environmental change, it is envisioned that energy consumers will mitigate greenhouse gas emissions by having a more active role in balancing supply and demand in the smart grid [27,28]. Like Azad and Ghotbi [29], in this review, the smart grid is considered an "electricity network that can intelligently integrate the behaviour and actions of all users connected to it, in order to efficiently deliver sustainable, economic, and secure electricity supplies." We argue that this current definition of the smart grid falls short since it lacks the incorporation of other commodities, such as natural gas and temperature-controlled water (both services applied in heating and cooling systems). The energy system is likely to progress towards a future where renewable technologies, multi-energy arrangements and novel market dynamics are prevalent. However, such transitions are not without complications. For instance, Furszyfer et al. [30], explore the cultural challenges that may arise in adopting smart energy systems, while Stephens et al. [31] highlight the importance of culture in supporting a reliable energy system. Additionally, existing retail electricity market structures must overcome many technical (such as gathering, managing and analysing vast quantities of data), socio-economic (enabling consumers to actively participate in the retail electricity market), and regulatory challenges (administration, regulation and operation of emerging business models) to become highly optimised.

The conventional business models of energy suppliers are being challenged by the accelerated development of distributed energy resources (DERs). Furthermore, discussions to date concerning liberalised retail electricity markets aim to optimise the energy market and encourage energy suppliers to provide a sufficient degree of active end-user participation [32]. In this context, this paper suggests that customer engagement strategies are likely to be the foundation of futuristic market structures over the next decade. It is clear that there is a necessity for establishing transparently functioning retail electricity markets to support smart grid development, especially with an urgent requirement for society to secure an efficient and economical energy supply while achieving carbon neutrality targets.

This study is novel in that it first establishes a definition of customer engagement in retail electricity markets. Second, in this study, highly cited papers and popular literature on the topic of customer engagement are scrutinised, and three key strategy themes emerged, these are: 1. 'Customer Focus', 2. 'Tariff Design' and 3. 'Innovation'. Third, the study systematically provides a comprehensive review of these customer engagement strategies in retail electricity markets. Finally, the study identifies the technical, market and social requirements to deliver an innovative retail electricity market structure to decarbonise society. The crucial and novel policy recommendation of this study is that integrating market mechanisms and technology (i.e., cross-linking across the three customer engagement strategy themes) is required to ensure robust and efficient retail electricity market operation as society advances to a net zero economy.

This paper is divided into seven sections. Section 1 provides the background and introduces the research question on the role and relevance of retail electricity markets and the importance of customer engagement. Section 2 describes the systematic review process. Section 3 overviews retail electricity markets. Section 4 discusses consumer inertia, consumer data and vulnerable customers. Section 5 describes tariff design, considering aspects such as demand response and altering customer behaviour. Section 6 presents the opportunities emerging to enable an optimal retail market design. Section 7 discusses the necessity of integrating customer engagement strategies into electricity markets and concludes with key recommendations.

2. Methods

A systematic literature review methodology was applied to determine the state of knowledge on retail electricity markets. This methodology "uses rigorous methods to bring together the results of primary research to provide reliable answers to particular questions" [33]. The process assists with understanding the multiple facets of the topic and establishing the potential gaps in the literature. To achieve a robust systematic literature review, the following steps were adhered to 1) identification of the key terms in the literature, 2) collation of academic papers, industry reports and popular literature, with topics driven by the identified key terms, and 3) eligibility screening of the collated literature.

In the first step, identification of the key terms associated with retail electricity markets and customer engagement was performed. This was achieved using a data analysis platform called 'CorText Manager' and a text corpus derived from the 'Web of Science' literature database. Text formatted contents and metadata derived from a selection of collated documents is identified as a text corpus [34]. The text corpus was constructed using a query in the 'Web of Science' advanced search tool. Terms such as 'Retail electricity market', 'Customer' and 'Consumer' were input, and the year range parameter was set to between 2000 and 2021. The 'Web of Science' search returned 256 results, each consisting of the title and abstract. The resulting initial list of 256 resources was

Fig. 1. “CorText” network map developed using key terms extracted from the complete set of 205 academic journal abstracts. Source, authors.

scanned for eligibility and refined to 205 individual articles specific to retail electricity markets. By employing the ‘CorText Manager’ platform, the text corpus of the ‘.csv’ file format was uploaded and parsed to create a ‘SQLite’ database file. Next, a terms extraction script was initiated to identify terms pertaining to the text corpus automatically. Fig. 1 shows the network map generated, which graphically displays the relationship between the extracted terms and the frequency of occurrence.

The key terms were clustered (e.g., ‘Load profiles and billing’, ‘Markets and efficiency’ and ‘System reliability’). Furthermore, the size of the triangle indicators represented the prominence of each extracted key term across the journal abstract sample. The fundamental purpose of the network map diagram was to direct article collation, ensuring that no significant aspect of retail electricity markets and customer engagement was unexplored. Building upon the understanding derived from the key research terms in step one, the second stage of the systematic review commenced, collating academic papers and industry reports.

Fig. 2. Systematic literature review methodology diagram. Source, authors.

High impact papers were identified from the initial 'Web of Science' collection of abstracts. By combining key search terms derived from the network map visualisations, journal articles, industry reports and other resources such as book chapters and online sources were collated. The final stage was an eligibility screening of the 220 collated resources. Duplicates were excluded, and papers were weighted depending on their relevance to the research. As a result some papers were excluded. The systematic literature review methodology led to approximately 149 final articles specific to customer engagement in retail electricity markets for inclusion in this paper. Fig. 2 presents a flow diagram that highlights the application of the systematic review process.

3. Retail electricity markets

Retail electricity markets consist of competitive individual retailers which operate as a monetary intermediary between final electricity customers and wholesale electricity exchanges [35]. For clarification, this study extends the economic definition of a retail electricity market to a techno-economic framework, which could incorporate and co-ordinate the customer engagement strategies discussed. Historically, retail electricity markets have emerged because of the vertical unbundling of energy utilities. Thus, modern electricity retailers act as separate entities from their generation, transmission, and distribution counterparts to arrange the delivery of this complex commodity to consumers [36]. There is no real consensus on what electricity retailers are precisely [37–39]. However, we consider that electricity suppliers fundamentally procure electricity from the wholesale electricity market, or alternatively directly from large-scale generators, and organise for the procured electricity to be dispatched to consumers via the transmission and distribution networks [40].

Electricity is bought and sold using the different trading floors of the wholesale electricity market, namely, the futures, the day-ahead, the intraday and the real-time markets [41]. In addition, retailers can use financial instruments traded on exchanges to hedge the risks associated with wholesale price volatility [42]. Qiu et al. [43], describe electricity retailers as 'self-interested' market entities since their main aim is to ensure maximal profits by offering optimal pricing arrangements to end-users while adhering to market regulations. It is important to identify that electricity retailers are limited in providing value-added services compared to other industries. The major limitation is the given nature of electricity, as it cannot be readily stored like other commodities (e.g., natural gas or crude oil). Other limitations include: 1) transmission and distribution of electricity are generally not managed by retail suppliers; 2) electricity is considered as an intangible, homogeneous and essential good, so the opportunity for product development and marketing is reduced [35]; 3) retailers are exposed to remarkably unstable wholesale prices, and revenue is generated from rather inflexible downstream tariffs and; 4) customer engagement behaviour is presently somewhat inactive [36].

With so many complexities in how electricity markets operate and limitations regarding the provision of electricity, power system stakeholders are faced with tackling the widely asserted energy trilemma concept, which refers to balancing security, affordability, and sustainability regarding energy access and consumption. Billimoria and Poudineh [44] state that "the classic challenge for electricity market design is to provide reliable and secure electricity at least cost to consumers while promoting consumer's preferences." The retail electricity market has recently advanced to confront this challenge and accommodate the expanding proportion of DERs, the extensive adoption of smart meters and the development of distribution infrastructure, which has advanced to harness both data and electricity [45]. Competition within retail electricity markets is important in providing optimal energy prices and service quality to consumers. Competition levels are inferred in a given marketplace by examining each retail energy company's market share or using quantitative metrics such as the Herfindahl-Hirschman Index [46]. These metrics are relevant in a liberalisation process and prove to regulators and the consumers that a retail market is functioning, but they do not examine the effectiveness or otherwise of customer engagement strategies. As society moves forward with the net zero transition, the interaction between economic frameworks (e.g., current retail electricity market structures) and emerging customer engagement strategies (e.g., smart metering and dynamic pricing) needs to be assessed for decision-makers as we follow a net zero decarbonisation pathway heavily dependent on technology embedded in the distribution grid and actively trading prosumers.

3.1. Customer engagement strategies

It is clear that retail electricity markets are evolving with customers actively participating or 'engaging' to force further electricity market liberalisation, drive changes in behaviour, improve energy efficiency and reduce emissions [23,31,35]. Liberalisation, in the context of the electricity sector, generally refers to the relaxation of regulatory or economic restrictions pertaining to wholesale and retail electricity markets (i.e., the establishment of more diverse markets regarding wholesale generator companies and retail suppliers, respectively). However, this study considers further liberalisation of retail markets and postulates that retail electricity markets will be developed to harness emerging technologies. On this basis, with the proliferation of renewable technologies and associated market dynamics, unforeseen regulatory and technical barriers and policies are emerging which prevent the robust integration of customer engagement strategies, which are primarily comprised of technical solutions. Although positive results of some customer engagement strategies are now becoming visible (e.g., demand-side management for peak power reduction and peer-to-peer electricity trading to enhance renewable energy deployment and grid flexibility) and such engagement or active participation is leading to the removal of barriers and the implementation of mitigating actions in the retail electricity market.

Contrastingly, in some countries retail electricity suppliers conduct business in a profoundly regulated market, with profit margins somewhat restricted (e.g., In GB (Great Britain), Ofgem (Office of Gas and Electricity Markets) have a 'Default Tariff Cap' in place to limit the amount that electricity suppliers can charge certain consumers for a unit of electricity) [47]. Thus, a technical, regulatory and socio-economic balance is likely to be required to enable customer engagement strategies to flourish and ensure suppliers can operate successfully. Examples of these challenges include: 1) managing and gathering insights from the vast quantities of consumer and generator data (technical challenge), 2) with emerging innovative business models, deciding who will administer and regulate their functioning and ensure they operate in the consumers' interest (regulatory challenge) and 3) enabling and promoting customers to actively participate in the retail energy market, while simultaneously supporting vulnerable customers (socio-economic challenge).

Customer engagement is, in essence, the bi-lateral relationship between customers and the retail electricity market. In this study the terms of 'consumer' and 'customer' are often used interchangeably. However, for clarity, it can be assumed in most cases that the consumer consumes electricity whereas the customer purchases it. Electricity customers are categorized into residential, commercial, or industrial sectors according to typical usage. We consider three novel ways customers can engage with the retail electricity market. First, by making informed decisions due to deeper liberalisation surrounding the choice of electricity supplier or tariff. Second, by adjusting consumption by way of incentivized prompts from DR programmes. And third, prosumer activity via P2P trading and other innovative business models. Prosumers are defined as proactive consumers, or alternatively, individuals or collectives that are both energy consumers and/or producers [48,49].

Electricity price information, price comparison tools, customer service metrics, and level of consumer protection are all important aspects for consumers to make informed decisions regarding their choice of

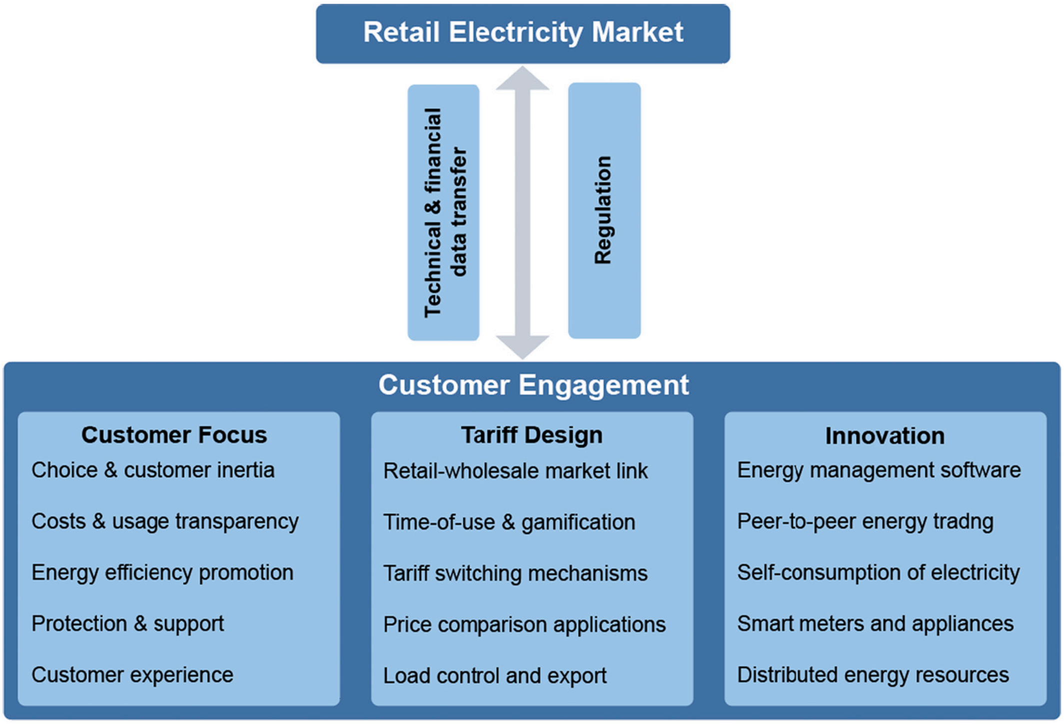

Fig. 3. Conceptual link between retail electricity markets and customer engagement. Source, authors.

energy supplier. The heart of demand response is tariff design, where the electricity cost varies by time-of-use, in contrast to conventional fixed pricing arrangements. Thus, DR avails of the latest developments in 'Internet of Things' interconnectivity and engagement methodologies (e.g., smart meters, gamification, incentives as well as use of EVs, smart appliances and efficiency targets). Prosumer activity hinges on DERs such as battery energy storage (e.g., Tesla Powerwall, SonnenBatterie and solar PV integration with such storage technology), smart appliances and other microgeneration at the distribution level. Furthermore, prosumer activity is heavily innovative and enables energy arbitrage, meaning those with a surplus of electricity can be financially rewarded via net metering in a peer-to-peer market. Fig. 3 shows the conceptual link of these strategies in a retail electricity market framework, and this study postulates that the crucial link between the customer engagement concept and the retail electricity market can be derived as the bi-lateral movement of technical information and financial data related to usage. Moreover, with emerging market structure paradigms, regulation also features as a connection between the market and customer engagement strategies.

Table 1
Levels of liberalisation in retail electricity markets. Source, authors.

Country	Number of retail electricity suppliers in country	Population (million)	Level of liberalisation	Average annual Price (£)	Number customers (million)
Australia [56–60]	53	25.7	Medium	494–1200	7.2
Brazil [61–63]	12 plus others	214.7	Low	235	81
China [64–66]	2 major + c.* 6400 others	1444.2	Low	325	c. 658
France [67,68]	2 major + at least 8 others	65.4	Low	721–754	c. 39.3
Germany [69,70]	Over 800	84.2	Medium	956–1506	c. 27.5
India [71,72]	c. 100	1398	Low	41–74	c. 199.5
Italy [45,73]	373	60.3	Medium	924	29.5
Japan [74]	at least 200	125.9	Medium	1129	c. 80
Poland [75]	4	37.8	Low	556	c. 12.93
Republic of Ireland [76]	12	5	Medium	900	c. 2.67
Russian Federation [77]	124	146	Low	291	280
South Korea [78]	1	51.3	None	761	21.5
Spain [79,80]	333	46.78	Medium	523	c. 29
UK [81,82]	44	68.39	Medium	1138	28
USA [83–85]	3300	333.74	Low/Medium	1056	154.99

c. = circa.
None = monopolistic economic model.
Low = very little choice in the retail supplier space.
Medium = alternative choices available to the customer.
High = majority of consumers are on dynamic tariffs to help balance supply and demand, consumers have further freedom in regard to choice of energy supplier(s), peer-to-peer trading systems are implemented, permitting energy arbitrage and supporting the power system at the distribution level.
[Note: Customers may not have access to all suppliers in the country, as the number of suppliers available to a given customer varies by region within the country.]
[Note: To assign a level of liberalisation to an entire country is challenging and perhaps an erroneous assumption, as levels of liberalisation vary at regional level in some countries.]

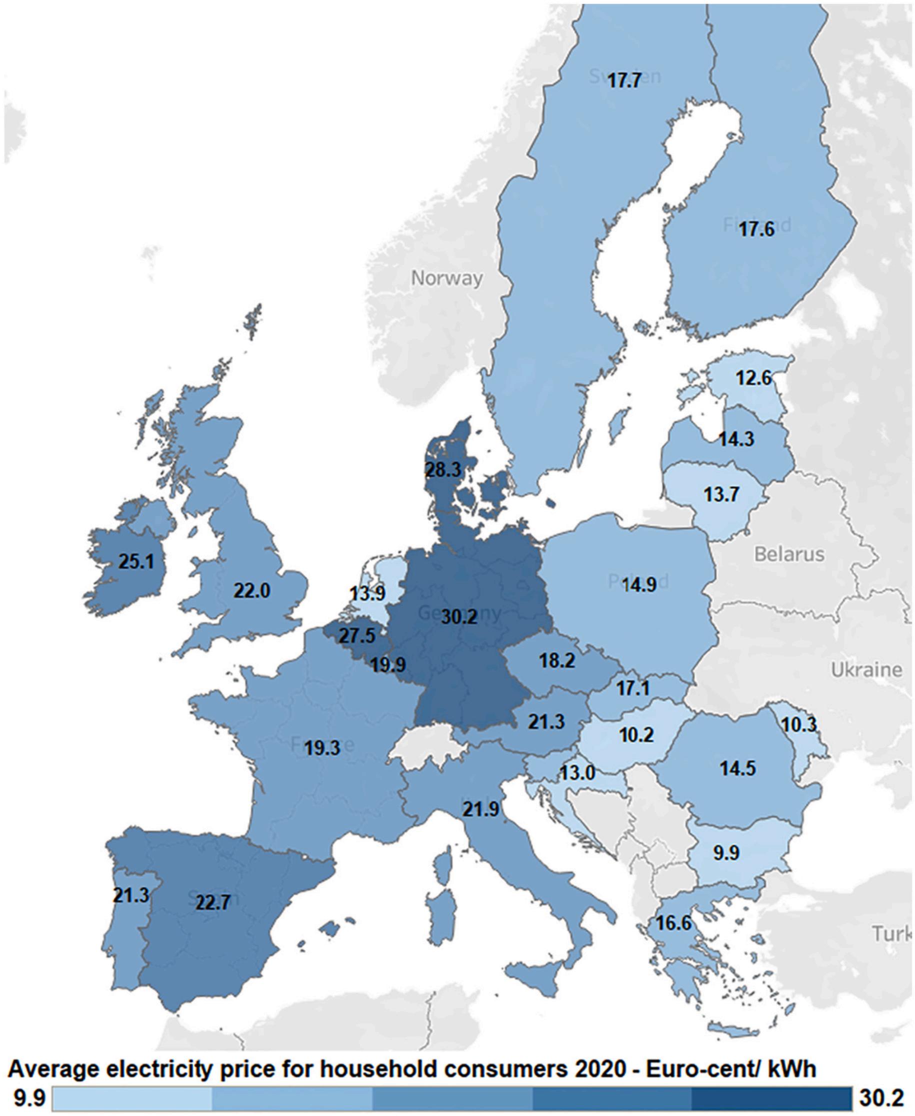

Fig. 4. Average electricity price for household consumers 2020. Prices represented in Euro-cent/kWh and includes all taxes and levies. EU countries and the UK. Source: authors, compiled from [87].

3.2. Traditional and emerging retail electricity pricing arrangements

How do retail electricity pricing arrangements traditionally work, and where are they heading? Retail electricity pricing arrangements and tariffs are the financial intermediaries between customers and retailers. Regulators and policy-makers see liberalisation as a gateway to "affordable prices, good standards of service and a selection of offers that caters to their diverse and evolving needs" [50], but is this true? The answer is yet to be 100% realised; nevertheless, this review study postulates that incorporating customer engagement strategies (in particular, the "Customer focus" strategy theme) in the retail electricity market is likely to meet consumers' diverse and evolving needs.

This paper defines liberalisation as the relaxation of restrictions and the implementation of mitigating actions in retail electricity markets to promote free competition among suppliers and protect consumers from a financial and power reliability standpoint. On balance, the liberalisation of electricity markets worldwide has been successful, creating a 'fair playing field' for consumers and suppliers [51]. Furthermore, Ghazvini et al. [35], acknowledge that liberalised retail electricity markets can better promote the integration of distributed renewable energy resources in the grid, as distributed generation units can technically and economically be positioned in this market model. Contrastingly, retail competition has been considered by some energy system stakeholders as a controversial topic, as some liberalised electricity markets have experienced failures historically and more recently. For example, the California Electricity Crisis of 2000–2001 [52], the 2021 Texas power crisis [53] and the collapse of Bulb Energy [54] in GB, which entered Energy Supply Company Administration in 2021. These failures revealed significant weaknesses in market policy, regulator intervention and the capability of retailers to appropriately hedge against wholesale electricity price volatility.

Table 1 provides some data gathered for ten of the G20 countries and a few European Union (EU) countries, who are among the largest greenhouse gas emitters and electricity consumers in the world. It shows the inconsistency in the number of suppliers relative to population size and indicates the liberalisation. This paper classifies three levels of liberalisation: 1. Low (very little choice in the retail supplier space), 2. Medium (alternative choices available to the customer) and 3. High (majority of consumers are on dynamic tariffs to help balance supply and demand, consumers have further freedom regarding choice of energy supplier(s), peer-to-peer trading systems are implemented, permitting energy arbitrage and supporting the power system at the distribution level). To assign a level of liberalisation to an entire country is challenging and perhaps an erroneous assumption, as levels of liberalisation vary at the regional level in some countries, especially in countries such as the USA, where electricity market policy is set at the state-level and as such, electricity markets are generally either traditionally regulated or competitive, with many differences between competitive retail markets depending on the state regulations [55]. In this context, the USA is assigned a 'Low/Medium' level of liberalisation to reflect this. Electricity market liberalisation has taken thirty years in some countries, and others have observed very little liberalisation, such as South Korea and Poland. Therefore, the main concern here is how can energy system stakeholders and policy makers deploy significant levels of renewable technology (e.g., smart meters, smart appliances, EVs, heat pumps and rooftop solar etc.) over the next thirty years without active customers and a regulatory framework with supporting standards for the consumer and industry.

Retail electricity prices also vary between suppliers and also differ depending on location. Fig. 4 shows that even across the EU and the UK, electricity prices for domestic consumers can vary by country despite liberalisation measures. The significance of this is that each country has different energy policies, generation portfolios and levels of reliance on imports. The architecture of pricing structures has a substantial influence on the magnitude, type and timing of electricity demand [36]. Moreover, how pricing structures are designed effects business cases for renewable technology, smart metering equipment and other decarbonising modalities. There are two types of pricing structures typically employed, fixed rate and variable rate. The provision of electricity requires demand and supply to match in real-time. Therefore, retailers are exposed to risk when arranging to procure electricity from the fluctuating wholesale market. To effectively shield the end-users from volatility risks, most electricity customers are offered fixed price contracts, which provide a consistent electricity price regardless of spot price variability [35]. In a given competitive retail electricity market, the market concentration is low, and there are numerous pricing arrangements available, leading to distribution of retail electricity prices. In Nelson et al. [86], the distribution of retail prices is considered as welfare-enhancing, but the authors also highlight that there may be a fairness issue regarding consumers paying different electricity prices, as it is both a homogenous product and an essential service.

Suppliers offering fixed rate electricity tariffs charge their customers a rate which includes the supplier's profit margin and covers the wholesale electricity cost and operational expenses. As this pricing arrangement does not account for when electricity is consumed, it does not encourage consumers to adjust the load in accordance with daily or seasonal peak and off-peak prices [88]. Additionally, fixed rate tariffs exhibit no granularity as the price is constant for all periods and the price is generally set far in advance (e.g., a few months to a year) of the occurrence of usage [36]. On the other hand, dynamic pricing arrangements support DR programmes, with structures such as, time of use (TOU) tariffs, critical peak pricing, real-time pricing and peak-time rebates [89]. TOU tariffs are pricing arrangements that help shift consumer usage from peak demand times, with the most advanced TOU pricing arrangements responding simultaneously to adjustments in market prices [90]. With the proliferation of electric mobility, charging/discharging EVs will be a suitable contender for time-varying pricing arrangements.

Developing dynamic retail pricing arrangements is crucial for the efficient and equitable pass through of wholesale electricity costs to consumers. However, mitigating actions need to be implemented to protect consumers from excessive wholesale electricity prices during exceptionally volatile periods. In this context, if policy makers carefully decrease regulation and price controls associated with restricting competition, consumers are exposed to more options,. Furthermore, suppliers are encouraged to develop diverse and innovative products [35]. There are a range of unprecedented pricing arrangements arising from liberalised retail electricity markets. For example, TXU Energy in Texas offers its users free electricity at night, attempting to encourage its customers to consume when prices are typically low [32]. Another example is British supplier Octopus Energy's 'Fan Club' tariff, which reduces the electricity price charged to their customers as wind speeds increase. The tariff is available to communities close to Octopus Energy's wind turbines. However, this may be a limiting factor as it excludes consumers who are not within specified postcode regions [91]. There are also other 'green' tariffs available, which may be fixed or time varying pricing arrangements that include an increased share of renewable electricity. Green tariff structures are a decentralised consumer focused mechanism to support renewables and are beginning to be chosen by increasing numbers of customers. For example, in the Netherlands, the government prioritised the uptake of voluntary tariffs through tax exemption that lowered the cost of green electricity tariffs [92]. These green tariffs are typically more expensive than pricing arrangements that include only conventionally generated power [93]. Zheng et al. [94] explored consumers' willingness to pay for green electricity and found that socio-economic factors (such as education, income, environmental concerns, and renewable technology knowledge) substantially impacted consumers' willingness to adopt these types of tariffs.

4. Customer focus

The UK has been one of the early adopters of liberalisation in energy, water (excluding Northern Ireland and Scotland, which both have public organisations in place to deliver water services), transport and telecommunications and has already investigated increased customer engagement and participation in the retail electricity market [23,95]. Hence the focus in this section is on the approaches taken to progress consumer engagement. In retail electricity markets, switching rates indicate competition between suppliers and a metric of market liberalisation. This is because suppliers compete to enable more competitively priced tariffs to retain existing customers or expand their customer bases. Electricity customer switching rates have been used historically as a metric of market liberalisation. For example, in New Zealand, the Electricity Authority in 2009, determined that current switching rates "were insufficient to curb non-competitive behaviour by retailers and that the full benefits of retail competition had not yet been realised", p.90, [96]. If switching activity is to be employed as a metric of market liberalisation, it likely needs to be nuanced; as observing increased switching rates to 'green tariffs' or time-of-use dynamic tariffs can be interpreted as a positive result, but switching to tariffs which may not support the net zero transition to the same degree, could be observed as a negative result.

Customers should economically benefit from changing to competitively priced tariffs [96]. This work defines "switching behaviour as the process of changing a pricing arrangement with a new or current supplier", a definition developed based on the terminology applied in the GB 'Ofgem Consumer Survey', from 2020 [21]. In this study, the comparison of suppliers and pricing arrangements is also considered switching behaviour, for example, when customers browse different suppliers and tariffs on commercial and government owned price comparison websites [97]. Such competition provides financial benefits and improved satisfaction to engaged end-users, as they can choose from an array of competitive suppliers for the best offer from a price, service quality and carbon footprint perspective [98,99].

However, a question energy system stakeholders and policy makers need to address is whether active switching is going to improve competition in retail electricity markets over the long term or will it be a 'race-to-the-bottom'[1] in terms of electricity tariffs offered to consumers? While deeper liberalisation regarding consumer choice (i.e., improved supplier / tariff comparative information or alternative supply options via an integrated peer-to-peer market) is likely an important aspect of

[1] A race-to-the-bottom is a term given to a competitive situation, where a sacrifice such as reduced service quality or reduced labour costs is employed in order to undercut the competition.

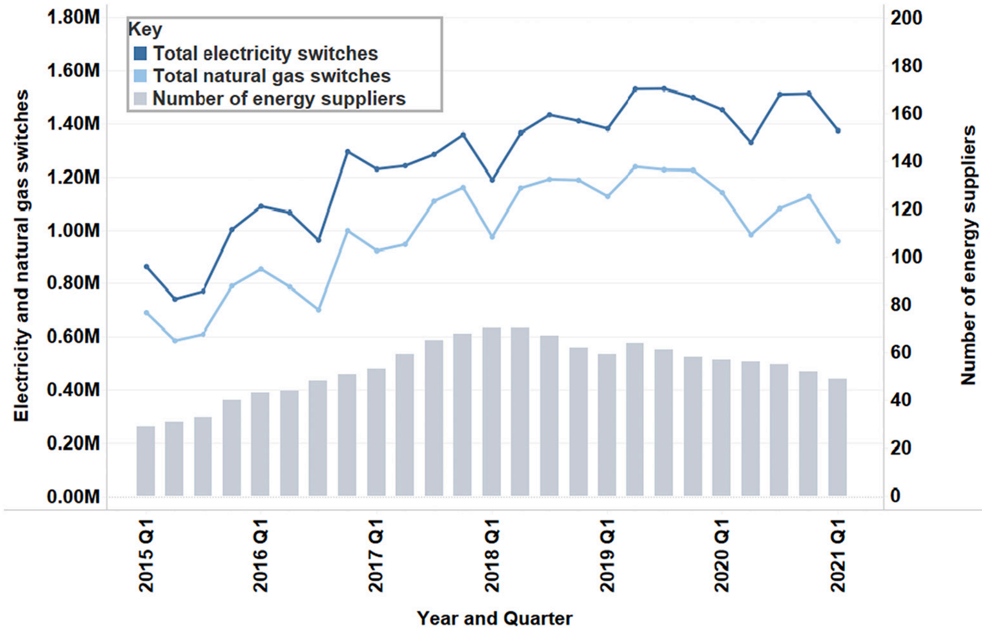

Fig. 5. Domestic customer switching behaviour against quantity of energy suppliers in GB (2015 Q1–2021 Q1). Source, authors, modified from [103].

future retail electricity market operation [100], it is reasonable to assume that electricity retailers have a desire to retain customers. A few potentially feasible alternatives to active switching could be price matching between suppliers or customer loyalty programmes (similar to schemes employed by supermarkets), this could save the consumer time and effort with switching and give them confidence that they are not excessively overpaying for their electricity supply.

Enhanced competition helps contribute to the net zero carbon transition by promoting the integration of renewable DERs [35]. In GB, many customers are not motivated to switch suppliers or tariffs. This is exemplified since around 60% of British customers are on a Standard Variable Tariff[2] (SVT) [101]. In 2014, Ofgem referred the market to the UK Competition and Markets Authority (CMA) to investigate low customer engagement. The CMA found that 'weak customer response' gave the incumbent suppliers market power, which they used to set excessive prices and discriminate against less engaged customers [102]. Since the CMA investigation in 2014, the number of suppliers participating in the British retail electricity market peaked at 63 suppliers in June 2018 (increasing from 22 suppliers in June 2014). However, this value has declined in recent years largely due to increasing wholesale electricity prices combined with the default tariff cap (39 suppliers as of September 2021) [103]. The competition between these retailers can financially benefit customers who are willing to look for more competitive deals [104]. Short-term domestic switching behaviour is somewhat related to seasonality, but it is primarily due to price change announcements by suppliers [105]. Moreover, long-term switching activity in Britain tends to correlate with the number of suppliers as illustrated in Fig. 5. Domestic switching in GB has been rising since 2014, but there was a recent significant reduction in this activity in the first half of 2020, coinciding with the COVID-19 pandemic [103]. As the quantity of suppliers increases, competition develops, and price disparity is likely to broaden. For those British customers who switch providers, the primary reason for switching was saving money, with 83% of respondents mentioning it as a motive in 2019 [97]. Therefore, as the number of financially attractive deals escalates due to retail competition, less engaged customers will become financially motivated to deviate from typically more expensive default tariffs.

4.1. *Customer inertia*

A prevalent challenge identified in retail electricity market research studies is the concept of consumer inertia [96,97,106]. Again, Ofgem in the UK has been leading the way on this. Consumer inertia relates to the significance of consumers' decisions regarding switching suppliers and, in particular, the tendency of customers to continue with an existing provider, even when superior pricing arrangements are available [107,108]. Reasons for consumer inertia include inadequate anticipated financial savings, low confidence in new retailers, intricate switching behaviours and strong loyalty to existing suppliers [45]. Additionally, complex tariff structures can further discourage customers from switching providers. Moneysavingexpert.com, a consumer-focused website in the UK, highlights that bills can be confusing, and it is often difficult for customers to understand exactly how much they are paying [109]. Moreover, Buhl et al. [110] highlights suggestions for the redesign of domestic bills, to reduce complexity and increase understanding. The results of trials carried out by Ofgem demonstrated that inactive customers can be prompted to switch using carefully designed personalised letters and emails. A remarkable 8.5% of the 1.1 million customers participating in the trials switched to new pricing arrangements and customers who switched saved an estimated total of £21.3 million since the trials began in 2017 [22]. Customer engagement is impeded by the trusting nature of customers and resulting loyalty to their supplier. For example, in GB, 65% of all households responded that they trust their supplier to charge a fair price for services, and this value rises to 77% in homes who do not have access to the internet [111]. An explanation is provided by Tyers et al. [101], suggesting that the status quo bias influences customers to perform actions that are not economically reasonable. Furthermore, Erdogan et al. [112], explains that consumer inertia can decrease retail market competitiveness and such inertia can be derived from a lack of economic benefit and switching costs.

Stagnaro et al. [45] suggest that in the future, inactivity associated with customer switching habits could be bypassed entirely by automating the switching process through third-party intermediaries (such as 'Uswitch' in the UK) [113]. Another type of switching scheme is

[2] A Standard Variable Tariff (SVT) is an electricity supplier's default tariff which is variable in nature, meaning a customer's electricity price can vary during the plan, typically according to wholesale electricity price hikes.

Fig. 6. Aspects of data and information which have a key role to play in customer engagement. Source, authors, modified from [96].

'collective switching', where a third party (such as 'Utility Bidder' in the UK) actively negotiates a better tariff on behalf of the group [114]. The principle behind collective switching is that large groups of users (potentially thousands) would have more bargaining power and avail of economies of scale, when compared to individual consumers acting independently [115]. Perhaps in the future, automated or collective switching processes could be integrated into an advanced big data digital framework centred between the customers and the suppliers. This framework would require balancing the vast quantities of customer preference parameters for retailer tariffs in real-time. However, Crampes and Waddams [116] indicate that introducing new market players (i.e., third parties) requires further research to fully understand the relationships between consumers, regulators and retailers.

4.2. Electricity data and information overload or scarcity

The absence of relevant and transparent electricity information is a barrier to customer engagement [22]. It is important that customers have readily accessible and clear information on costs to make informed decisions on pricing arrangement selection and day-to-day energy consumption [117,118]. Fig. 6 demonstrates the aspects of electricity data and information which have a key role to play in customer engagement. Regulators have made improvements to retail electricity market operation in some countries to ensure information provided to consumers is sufficient, for instance, programmes have been established to help consumers compare tariffs and are further supporting vulnerable customers [119]. Electricity customers have a knowledge deficiency regarding policy adjustments, the alternative options and how to effectively switch provider or pricing arrangement [99].

The price of electricity is one attribute of electricity services that influences switching activity. There are other non-price attributes such as call waiting time (i.e., when customers contact their supplier's customer service department for queries or concerns), length of contract, renewable energy (i.e., whether or not the supplier guarantees that the electricity supplied is generated from a renewable source), loyalty rewards and supplier type (i.e., new supplier or well-established supplier) [96]. When focusing on the price attribute of electricity services, He and Reiner [120] indicate that if customers are doubtful about evaluating their energy consumption and how their bill is calculated, it will also be difficult to forecast the savings possible from switching. They conclude that when households are more aware of their energy expenditure and available pricing structures, there will be an improved probability of customer engagement in the retail electricity market. However, Stojanovski et al. [121] suggest that there are limited observational indicators that consumers can interpret the link between their energy consumption behaviour and energy bill modifications.

Energy bills are typically received far after customers have consumed the energy; thus, energy usage and payment information must be provided in a consistent and timely manner [122]. With the advancement of ICT (Information and Communications Technology), energy customers are empowered to have more influence in the retail market than before. ICT has decreased information asymmetry, advanced transparency and developed customer value [123]. Customer value can be described as the "perception of what a product or service is worth to a customer versus the possible alternatives" [124]. By employing developments in ICT (such as digital marketing, recommender engines and software applications), connectivity between retailers and customers can be constantly sustained through user experience channels (such as email, social media, web platforms, mobile phone applications and smart home management systems) [125]. One development derived from ICT to support energy consumers with supplier and tariff selection is the price comparison website, an electronic intermediary that connects energy suppliers and consumers. Customers can browse a range of energy pricing arrangements based on their location, current supplier, typical energy consumption and preferred payment method. However, price comparison websites can employ marketing techniques to influence which energy deals are presented to the consumer, depending on the level of regulation in the jurisdiction. The returned pricing arrangements can then be ranked by savings, choice of supplier and customer service rating. Suppliers benefit from price comparison websites as it is a platform to communicate their pricing arrangements and serves as a framework to expand their customer base [126].

Perhaps in the future, real-time data on consumption and pricing information will be available to customers. Customers could then precisely observe at a high-resolution granular level how their consumption behaviour influences the price and how much they are being charged. Providing transparent pricing arrangement information is crucial for customer financial wellbeing, especially in light of the recent February 2021 power loss incident in the state of Texas. During a major cold-weather event, the Electric Reliability Council of Texas (ERCOT) declared an emergency. During this emergency, a provider based in Houston Texas called 'Griddy', was publicised for sending extortionate bills to Texans when the wholesale electricity price increased rapidly (Griddy had pricing arrangements in place, which directly exposed the wholesale price of electricity to their customers) [127].

4.3. Vulnerable customers

Vulnerable customers may be those groups in society who have low household income, are elderly, have a long-term illness or a disability. Furthermore, any energy customer can become vulnerable at any time (or even multiple times) in their lifetime due to short-term life changes (e.g., those experiencing grief, temporary illness, recent job loss or related life changes). Organisations in industry have made efforts to support vulnerable households, for example, EnergyUK's 'Vulnerability Commitment', which is a voluntary agreement open to energy suppliers of all sizes [128].

For low-income domestic customers, paying bills can represent a substantial part of their income; this issue is linked to energy poverty. Husnain et al. acknowledge that the term energy poverty is differently interpreted and illustrated from various perspectives [129,130]. Thus, one definition of energy poverty established by Pye et al. [131] is "where individuals are not able to adequately heat their homes or meet other energy service needs at affordable cost." Esplin et al. [58] indicate that energy poverty is typically related to factors such as large household size, family formation demographics, and consumption that exceeds the average. Energy-related financial hardship is also associated to fuel poverty. A household is said to be fuel poor if the occupants need to spend more than 10% of their income on fuel to maintain an adequate level of warmth [132]. Furthermore, some regions (e.g., Scotland) have legal definitions of fuel poverty developed from Brenda Boardman's (a prominent research fellow and campaigner against fuel poverty) 10% definition in her book of 1991 [133,134]. McLoughlin et al. [135] highlight that domestic energy customers principally consume electricity through space/water heating, cooking/washing appliances and lighting. Contrastingly, depending on location and infrastructure, many consumers use natural gas (or oil for those consumers in rural areas) for their space/water heating instead of electricity. For example, in GB, natural gas consumption across the domestic sector was 330 terawatt-hours in 2020 [136]. Electricity consumption efficiency is associated with the characteristics of such household appliances and systems and the building itself. In England, the energy performance of domestic properties can be quantified using the Fuel Poverty Energy Efficiency Rating (FPEER) methodology, which assesses such household aspects as the building fabric, heating system and lighting [137].

In recent years, the social implications of the zero-carbon transition have emerged, thus energy policies require a comprehensive review to facilitate an effective people-focussed just transition. In Carley and Konisky [138], the concept of a just transition is discussed and how those experiencing energy poverty and living in inefficient homes may be disproportionately burdened due to increasing energy costs and energy insecurity. Customers experiencing energy-related financial hardship are often inadequately regarded during the amendment of policies. This results in a range of directives that generate unsatisfactory distributional consequences, as funding typically concentrates on only the technological aspects (i.e., renewable energy penetration and energy efficiency) rather than harnessing a balance with social imperatives [139].

While adverse conditions of low-income groups may be driven by multiple factors (i.e., costs associated with food, clothing, commuting and caring responsibilities etc.), if energy is a factor (depending on individual household circumstances), Nelson et al. suggest that energy retailers must create a fairer deal to mitigate the sometimes extreme circumstances for their low-income customers [86]. Niromandfam et al. [140] discuss that real-time pricing is an effective structure to allow customers to participate in the power market. However, the authors recognise, particularly for vulnerable customers, that restrictive barriers (e.g., market participation complexity and volatility of market prices) are in place and their research study explores a risk hedging mechanism that aims to alleviate customer concern by shielding them from market risks.

Retailers should likely be responsible for assisting this demographic, with the support of electricity system regulators, by monitoring their pricing arrangement and if required, introduce a more appropriate tariff. This position is suggested because low-income households have expressed a willingness to reduce their energy bills [141,142]. It has also been inferred from qualitative interviews and quantitative market engagement surveys in GB, that those experiencing energy poverty require specific information and actionable guidance regarding suppliers, tariffs and grants [111]. Esplin et al. [58] suggest developing a targeted intervention related to subsidy-based frameworks to make energy more affordable for vulnerable and disengaged customers while preserving the benefits for other customers to remain active and engaged. Successful interventions implementing this approach, include GB's 'Winter Fuel Payment' (which provides around £2 billion each year to pensioners) and the default tariff and prepayment meter caps, which help protect less-active customers, including those who are in vulnerable situations [97]. Notably, the tariff caps are a regulatory restriction on energy price, potentially promoting further customer disengagement.

5. Tariff design: demand response and altering consumer behaviour

As some energy customers are progressively becoming more conscious of their carbon footprint, it is anticipated they will want to contribute to society with the responsible management of their energy consumption profiles [143]. However, for a minority of energy customers, carbon conscientiousness is likely not a key driver for efficient energy management (e.g., groups who deny climate change or households experiencing fuel poverty). Supporting active customer

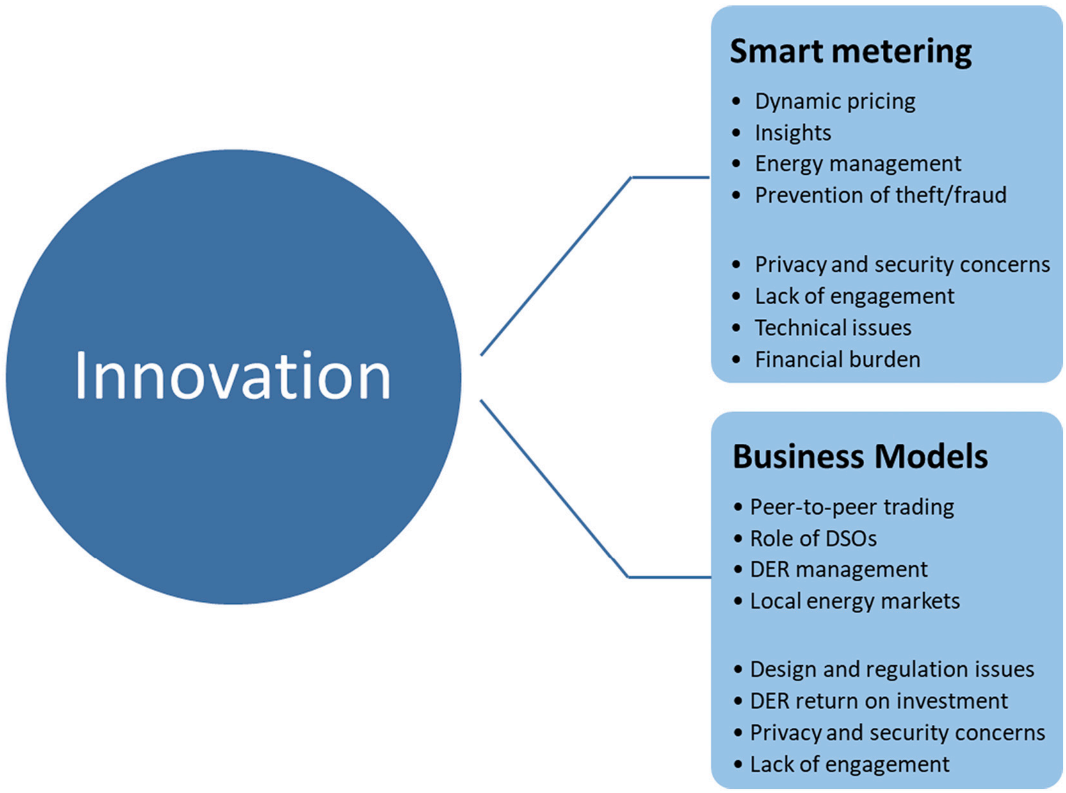

Fig. 7. Technical, regulatory and socio-economic innovation in retail electricity markets. Source, authors.

engagement in retail electricity markets through DR mechanisms and aggregation techniques will help to optimise the demand side of the energy system [89]. Reducing demand equates to the "generation of a similar amount of electricity. Furthermore, if one also considers the network loss, the impact of demand reduction will be even greater", p.44, [144]. Demand response programmes are a division of demand side management and aim to adjust customer energy consumption profiles away from specifically designated peak demand times [145]. There are essentially two types of DR programmes, price-based DR programmes and incentive-based DR programmes [146]. Alasseri et al. [144] suggest that in price-based DR programmes, the price adjusts according to the time, while in an incentive-based DR programme, consumers are motivated by receiving incentives for re-allocating energy usage. There is a significant opportunity to implement DR programmes in domestic environments. For example, UK households account for approximately 30% of overall UK electricity demand and an estimated 50% of peak UK electricity demand [147]. However, there is a range of customer engagement barriers to overcome to ensure DR programmes are fully utilised, for example, Parrish et al. [148] highlighted some significant barriers (such as familiarity, trust, perceived risk, perceived control, complexity, effort and user routines) for residential DR.

DR programmes adopt innovative technologies like smart meters and energy efficient appliances. Energy consumption data is extracted from these technologies, which allows behavioural insights to be gleaned from the data [149]. This ought to allow retailers and DR aggregators to understand their customer base and incentivise accordingly. 'Social nudges' can be combined with incentives for increased DR effectiveness. Social nudges use social comparison, a psychological concept, to compare the nudge recipient's choices with another individual or group, to persuade the nudge recipient to change their behaviour [150]. An example of a social nudge would be personalised home energy reports that show the consumer how their energy consumption deviates from their neighbours, with bespoke targets included to adjust their usage accordingly [151]. In Brandon et al. [152] they found that by using social nudges, up to 6.8% reduction in energy consumption was achieved (42,000 households participated in the study).

Demand response programmes will be instrumental in managing varying household habits, especially in light of the recent COVID-19 pandemic [153]. Cheshmehzangi [154] examines the temporary impact of lockdowns on household energy consumption and discusses potential long-term adjustments in energy usage if more people opt to work-from-home in the future. Gillingham et al. [155] point out that any time there is a major change in economic activity, such as that derived from the COVID-19 pandemic, there will be implications for the environment. They note that the long-term environmental effects of the pandemic are highly uncertain. However, Gillingham et al. note that should lockdowns continue for an extended period of time, workers and employers may become sufficiently comfortable with remote working even after the threat has passed. This would reduce travel but likely increase household energy use.

6. Innovation: smart meters, prosumer activity and emerging business models

In Nelson et al., p.158, [86] energy systems are described as an "intricate network of physical and economic infrastructure." On this premise, a conceptual link between smart metering technology (physical infrastructure) and retail electricity markets (economic infrastructure) can be established. This paper considers electricity smart meters to be the primary type of smart metering technology. However, other commodities and suppliers have their own specific smart technology (i.e., smart thermostats, smart gas meters or smart water meters) [156]. Smart meters can be defined as devices that can measure near-real time or real-time electricity consumption and communicate this recorded data with energy users [157]. This smart metering technology is designed to share information about the current energy prices and consumption between a household or business and the energy supplier.

Furthermore, enabling technologies such as smart plugs and appliances can be integrated with building energy management systems to automate household and business energy usage [93]. However, without customer engagement, the capacity for the smart grid to function optimally could be significantly reduced [142], as it is still unclear if the installation of smart metering equipment alone will be the only factor to substantially impact customer energy behaviour [158].

Smart meter roll-outs in various countries are likely to facilitate customer engagement in retail electricity markets, as it is expected that this equipment will enhance the rewards from active market participation [45]. Specific advantages of smart meters include consumption behaviour analysis, prevention of deceptive activities such as electricity theft, enhanced energy management and access to new dynamic pricing arrangements [159]. However, in the current literature on smart metering devices, it is clear that technology alone cannot enable optimal customer engagement and that roll-out policies should be complemented with mechanisms for behavioural change [160,161]. Even 'engaged' customers may still disassociate themselves from interacting with their smart meter shortly after installation. Moreover, many electricity customers are either unaware that a smart meter has been installed or are hesitant to respond to the price signals [93]. Chakraborty et al. [162] acknowledge that consumers have several concerns with smart meters, such as security and privacy of their information and health hazards (e.g., radio waves exposure and fire risk). Foley et al. [90] highlight that consumers perceive smart meters as an instrument that is limited to inform customers about their energy consumption, rather than as advanced equipment integrated with energy management systems to restrict energy consumption on a selective basis. Sovacool et al. [163] explore three 'resistance' dimensions in the UK smart meter transition, these are: 1) technical (e.g., meter range, malfunctions, supplier incompatibility and cybersecurity), 2) vulnerability and poverty (e.g., consumer misunderstanding, financial burden, supporting rural groups and lifestyle impacts) and 3) consumer resistance and ambivalence (e.g., defiance, privacy, health and apathy). Thus, further customer engagement is required in relation to education, information and encouragement to ensure smart metering technology is fully utilised, as well as developing the smart metering equipment to alleviate such actual and perceived risks. Carmichael et al. [164] discuss the 'informed adoption' of smart meters by raising low awareness of the benefits of smart meters (e.g., potentially reduced bills via new services like time-of-use pricing, carbon emissions reduction and combating power system inefficiency).

As the number of connection points to the network increases and an enormous quantity of energy information is now exchanged, preparing for cybersecurity threats and personal information leakage is critical [123]. This issue has already arisen in the Netherlands, one of the first adopters of smart metering technology. According to Pereira et al. [165], disregard of privacy issues led to reduced acceptance and postponed deployment by many years. Moreover, Véliz and Grunewald [26] suggest that four of the most prevalent privacy risks are 1) the inference of sensitive information, 2) discriminative customer segmentation, 3) multi-person data and 4) data aggregation. To support all retail electricity customers fairly, Iliopoulos et al. [142] discuss the benefits of placing extra emphasis on developing measures (such as educational programmes on cybersecurity) for a variety of socio-economic groups.

Relationships between energy grid components and participants are developing, as the energy transition involves more than just upgrading technologies [147]. Fig. 7 overviews two key aspects of current innovation in retail electricity markets (i.e., smart metering and business models). Innovative business models will drive social sustainability issues [166] and these innovative business models are being developed across the research domain to support the integration of customer engagement, for example, in Niromandfam et al. [167], where the authors discuss the design of a reliability insurance scheme, which is novel in the fact that it permits electricity consumers to set their supply reliability levels and make payments to the distribution system operator. The distribution system operator then uses this source of revenue to balance the supply reliability and reimbursement of consumers.

Electricity customers are becoming increasingly aware of the monetary aspect of energy and their carbon footprint, with prosumer activity rising gradually due to the expansion of DERs [142,168]. In a peer-to-peer (P2P) electricity market, prosumers are empowered to trade renewable energy locally and beyond geographic boundaries. The P2P market facilitates electricity trading, which occurs between two parties without the need for any intermediate entity. However, this is an area of significant research as there are possible detrimental impacts on the network if stringent constraints on the physical transfer of electricity are not supported [169]. The premise of P2P electricity markets is largely based on the concept of the sharing economy [170]. Prosumers have full control of their own DERs, and no additional incentives are needed to motivate prosumers to participate. Moreover, reduced computational time and ICT infrastructure are required due to its distributed nature [171]. With the advent of plug-and-play technology and P2P market arrangements, customers will be able to link to the grid at any time to purchase or supply energy [29]. Local energy markets are an emerging methodology for the energy system interaction between DERs and local end-users. Local energy markets can enable prosumer activity and have the potential to defer grid infrastructure upgrades [43]. Chen and Su [172] describe a market instrument that provides energy customers with a facility for occasional prosumer activity in addition to availing of existing electricity supplier services.

Many companies are adopting blockchain technology for developing P2P electricity businesses [123] and independent online marketplaces are emerging, such as Piclo in GB. Piclo essentially provides a platform for trading energy flexibility services online and hosts 'competitions' for flexibility providers to supply energy. The term 'flexibility service' is related to the ability of assets to adjust their energy generation and/or patterns of consumption in response to external signals [173]. Currently, the platform has a flexibility volume of over 4.5 gigawatts and over 200 flexibility providers [174]. Wesche and Dütschke [175] identify the critical success factors for an organisation to become an active electricity agent and highlight that attractiveness of the return on investment is vital. Despite all the emerging research and business models for energy flexibility products, Hamwi et al. [176] point out that this remains relatively uncomprehended in current energy systems. In this context, preliminary issues related to P2P platforms include: 1) business models and system design 2) ICT to connect stakeholders, 3) transactional layer for renewable assets and 4) blockchain technologies for the efficient transfer of currency [177].

7. Discussion & conclusion

Throughout this study, retail electricity markets have been identified as the potential techno-economic framework to support the demand-side of the energy system and to harmonise distributed renewable generation and storage technologies. This identification is somewhat based on the fact that electricity customers are generally already economically connected to the power system via their electricity supplier or utility, with some degree of customer protection or regulatory measures already established (e.g., tariff pricing caps or provision of information relating to understanding payments & bills, getting connected to the electricity network, switching supplier, supply interruption information, customer service and energy efficiency advice). While the definition of supplier and utility are essentially the same, for the purpose of the review study, we distinguished between suppliers and utilities. We referred to supplier when retail competition is established in a given country or region, and this implies that there are multiple retail electricity suppliers available for customers to choose from. On the other hand, the paper referred to utility when no retail competition is in place, instead a monopolistic electricity market model is established.

The aim of the paper was to review and discuss the customer engagement strategies which are emerging and could be implemented in retail electricity markets (e.g., peer-to-peer electricity trading), as well as those strategies that have already been established to some degree (e.g., smart metering equipment). We have proposed, for regions that permit retail competition, that retail electricity markets could be utilised to harness the different customer engagement strategies to ultimately reach climate neutrality objectives. While the focus of this paper is on retail electricity markets, in some regions of the world, no retail competition exists yet or policy makers have opted not to adopt such a liberalised market structure, so a research question arises for energy stakeholders and researchers. Is customer engagement best achieved if electricity customers are served by competing suppliers in a competitive retail electricity market, or by a monopoly utility? It is out of the scope of this study to suggest which economic market model is better or worse (i.e., monopolistic vs. retail competition), as both could be developed to include customer engagement strategies. All things being equal, energy system stakeholders in regions which do not permit retail competition (e.g., such as in many states in the USA), could enhance the role of the utility, to ensure that at least some of the customer engagement strategies discussed in this paper are implemented and cross-linked. It is worth noting that discussing the advantages and disadvantages of each electricity market model (e.g., vertically integrated, retail competition or consumer ownership models) in the context of 2050 net zero targets would be a beneficial review study.

The customer engagement strategies discussed are typically technical options. However, we have endeavoured to also review the socio-economic impacts of each strategy. As society intensifies efforts to meet net-zero targets, it is widely asserted that electricity consumption patterns should better align with renewable electricity production (e.g., wind and solar) and constraints associated with transmission and market operations. A detailed sensitivity analysis could be compiled to compare the effectiveness of each customer engagement strategy, in regard to adjusting consumer behaviour and achieving new electricity consumption patterns. However, the degree to which customer engagement strategies will work might depend on the degree of participation of the customer, unless autonomous functioning is implemented (e.g., a software system implemented in a household or business which automatically tracks a novel and dynamic retail electricity price, and adheres to price signals to reduce or reallocate load).

It is reasonable to presume that energy system stakeholders are likely already familiar with the individual customer engagement strategies discussed in this study. These strategies relate to a broad range of technical options available to support the electricity sector going forward (e.g., demand response, energy management systems and P2P trading etc.). On this basis, we propose that there needs to be a system that links & harmonises these technologies, and this study explores the idea that retail electricity markets, in regions in which permit retail competition, could be advanced to become state-of-the-art techno-economic systems which help achieve such harmonisation. This gives rise to a research question, what sort of retail market structure is proposed in this paper? To answer this question, no retail structure is proposed… yet. Instead, we have endeavoured to come to a consensus of the next steps or research directions for developing retail electricity markets in regions which have elected to have retail competition in place. In this context, this paper sets the stage for a next phase of research & design, a retail electricity trading and analysis platform for customers, regulators and suppliers which adopts and cross-links customer engagement strategies described in this paper (i.e., peer-to-peer electricity trading, demand response programs, tariff arrangements, wholesale-retail price interaction, support of vulnerable consumers, provision of transparent energy and financial information and integration with home management systems etc.).

It is clear from the reviewed literature that future retail electricity market pricing arrangements should adapt to the new technologies being developed, in particular DR programmes, smart metering devices and increased prosumer activity in order to reach net zero. In Lo et al. [178], they note that any financial engagement with suppliers and customers should also be designed to accommodate the following: 1) encourage customers to shift demand to facilitate optimal smart grid operation 2) promote affordable energy access for those experiencing energy poverty and 3) allocate costs, benefits and risks equitably among customers. These concepts should be considered when designing innovative retail electricity pricing arrangements. Additionally, pricing arrangements should send clear and standardised price signals to customers, allowing a transparent and straightforward process for switching supplier/tariff. Current retail electricity market suppliers have adopted the standard practice of retaining existing customers on more expensive contracts once their attractive fixed term switching deals have expired, unless customers actively choose an alternative supplier/tariff [126]. Watson et al. [179] discuss the idea of multi-supplier models, which would allow energy customers to have more than one energy provider. Currently, retail energy customers are protected from aggressive wholesale price fluctuations through fixed tariffs. With the advent of DR programmes and increasing customer engagement, fluctuations in wholesale energy price due to demand reasons may be controlled. Perhaps there is scope to integrate both markets to a further degree as the risk of price volatility is reduced. Zhao et al. [180] highlight that the wholesale price should not be assumed as a random variable. Thus, the closed loop interaction between the wholesale and retail electricity price is required.

Foley et al. [90] express the importance of harmony in energy policy, electricity system planning, digital technologies and market design. Thus, integrating policy is essential for progressing to a future retail electricity market. Tayal et al. [181] acknowledge that the challenge for energy system stakeholders is balancing three elements: how to provide affordable, reliable, and clean electricity to all customers. Thus, future retail electricity market design requires sophisticated processes in place to support those who are less likely to engage with the market. However, a customer-centric approach could be adopted to improve the end-user's experience. This approach may be implemented by assessing consumer requirements, applying principles of behavioural psychology and encouraging optimal market participation. In Darby [147], it was concluded that five themes emerged as contributory factors to a good customer experience; these were comfort, cost, connectivity, control and care. Data analysis and artificial intelligence techniques relating to data science are steadily being developed, and they can contribute significantly to better real time operations of retail electricity markets to facilitate net zero targets. Radenkovic et al. [182] demonstrate that new research will focus on real-time business intelligence and big data analytics and its application in the energy markets. By integrating artificial intelligence techniques, researchers can develop complex engines to tackle smart grid decision-making problems, for example, in Lu et al. [183] an algorithm for dynamic pricing in DR programmes using reinforcement learning, an application of artificial intelligence was proposed. Transactive energy systems also have a role to play in retail electricity markets in this century and the application of Internet of Energy is an area of future research. The Internet of Energy concept is derived from the parent Internet of Things field of study and relates to the digital relationship between the grid infrastructure and emerging decentralised technologies [184].

This paper examined the range of customer engagement strategies in retail electricity markets, identified gaps in the literature and established a body of knowledge for energy system stakeholders, policy makers and researchers. First, current retail electricity market design and operations were examined, and the definition of customer engagement was established. Following on, the emerging retail electricity market research trends were identified as: 1. Focusing on the retail electricity customer, 2. Behavioural change of electricity consumers with demand response and dynamic tariffs 3. New technology such as smart meters and the proliferation of prosumer activity as innovative business models develop. To conclude, this review study has identified eight key customer engagement areas for future research to permit optimised and transparent functioning retail electricity markets. These

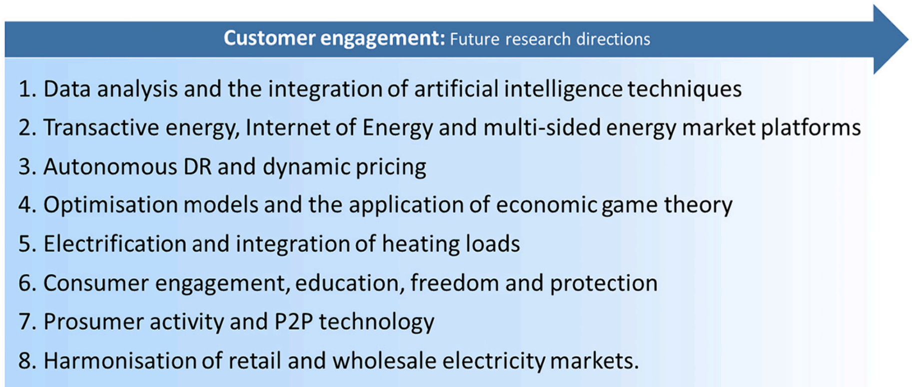

Fig. 8. Future research directions of customer engagement for retail electricity market design. Source, authors.

areas are displayed in Fig. 8 and are as follows: 1) data analysis and the integration of artificial intelligence techniques, 2) transactive energy, Internet of Energy and multi-sided energy market platforms, 3) autonomous DR and dynamic pricing, 4) optimisation models and the application of economic game theory, 5) electrification and integration of heating loads, 6) consumer engagement, education, freedom and protection, 7) prosumer activity and P2P technology and 8) harmonisation of retail and wholesale electricity markets.

The two main findings and the single policy recommendation of this review study are as follows:

1. This study identifies that literature on customer engagement revolves around three key strategic themes, namely ‘Customer Focus’, ‘Tariff Design’ and ‘Innovation’. A comprehensive and comparative review of these customer engagement strategies in retail electricity markets was compiled. Throughout this review, technical, market and social requirements to deliver an innovative retail electricity market structure to decarbonise society are identified.

2. The eight key customer engagement research areas for future retail electricity market design were established. These include improving the energy customer experience with the application of a customer-centric approach and the implementation of big data analytical techniques to infer insights from the increasing volume of high-resolution energy information.
3. The crucial and novel policy recommendation of this paper is that the integration of market mechanisms and technology (i.e. cross-linking across the three customer engagement strategy themes: 1. ‘Customer Focus’, 2. ‘Tariff Design’ and 3. ‘Innovation’) is required to ensure robust and efficient retail electricity market operation, as society advances to a net zero economy.

With consistent price hikes in both wholesale and retail electricity prices and an urgency to achieve emissions reduction targets, the optimal adoption of customer engagement strategies will be the catalyst that will harness arising market variables and help advance towards a sophisticated retail electricity techno-economic framework and a net zero carbon future.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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