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Developing future retail electricity markets with a customer-centric focus

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ABSTRACT

Future retail electricity markets require development to accelerate the net-zero carbon transition. Adopting a customer-centric approach to market design is necessary to fully utilise smart grid technologies. In this perspective we postulate that empowering energy consumers to become an integral component of the smart grid will lead to heightened renewable energy deployment and network flexibility.

1. Introduction

Society must advance to an environmentally sustainable post-carbon world by reducing greenhouse gas emissions. Globally, governments have established initiatives and frameworks to achieve carbon neutrality, exemplified by the net-zero emissions by 2050 target set in the United Kingdom (UK Government and "Energy White Paper, 2020). Developing efficient renewable generation technologies is crucial to achieve such ambitious targets and transition to a low carbon energy system. However, as renewable technology penetration levels increase, the implementation of supporting market-based mechanisms and ancillary services is necessary to balance complex time-varying differences between demand and generation (Davis et al., 2018).

The modern energy network, identified as the smart grid, is a fundamental component of societal infrastructure and is evolving at an unprecedented pace. Major economies around the world are deploying smart metering devices in vast quantities to fully integrate end-users into the energy system. Smart metering technology enables the automated collection of fine-grained consumption readings and facilitates dynamic pricing arrangements, which depend on the time-of-day to reduce energy demand (Tushar et al., 2018). The retail electricity market is embedded in the smart grid as a customer-facing financial entity comprising the incumbent and new competitive energy suppliers. The existing retail electricity market structure must not succumb to stagnation, as continued development is necessary, with it being an integral monetary feature of the smart grid.

At the distribution level of the smart grid, many elements require further integration with the retail electricity market. These include: dynamic pricing arrangements, distributed energy resources (DERs), electric vehicles (EVs), heating and cooling networks, smart metering technology, energy management systems and peer-to-peer (P2P) energy trading. All these elements have a common thread, the energy customer. A customer-centric approach is one significant methodology applied to future retail electricity market design. By maximising energy customer engagement and availing of their consumption flexibility, this end-user focused approach could optimise the utilisation of smart grid technologies. Therefore, enabling an adaptive retail electricity market and ultimately hasten the net zero carbon transition. Fig. 1 highlights the smart grid components which involve active customer engagement.

We establish our perspective on the key concepts for developing future retail electricity markets with a customer-centric focus. In this context, we first capture the changing energy infrastructure landscape with the shift from centralised conventional thermal power plants to distributed renewable generation and energy storage. Our discussion progresses to the heart of the piece, the embedment of customer-centric energy policy, which considers the emergence of modern retail electricity markets and customer engagement which encompasses tariff switching, smart meters, demand response programs, behavioural changes and prosumer activity (a prosumer is considered an energy consumer and, simultaneously, an energy producer (Kanakadhurga and Prabaharan, 2021)). Following on, we then situate our perspective on supporting communities in the energy transition, especially vulnerable

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groups. Finally, this short communication concludes by discussing peer-to-peer energy trading, which is an emerging innovative business model to support renewables deployment and grid flexibility.

2. The changing energy infrastructure landscape

The power system is transitioning away from the well-understood traditional paradigm, as the penetration of converter-based technologies increases (Al kez et al., 2020). Furthermore, the power system is becoming part of a wider smart energy system with sector coupling across electricity, heating and cooling, industry, commercial and domestic buildings and transportation (Lund et al., 2017). Historically, the grid was built to support one-directional power flow from centralised generation with beneficial system inertia characteristics. Given the intermittent nature of renewable distributed generation, there are growing implications regarding dynamic stability. New voltage and frequency regulation techniques are required, which support the network during normal and abnormal operations. A challenging problem for grid operators is system planning with large-scale distributed generators and consumers' smart appliances. One solution is implementing a market-based control mechanism, which harnesses the economic power of the electricity market, to co-ordinate such spatially distributed technologies (Gourisetti et al., 2021).

The energy system is becoming increasingly dependent on renewable generation technologies such as wind turbines, which are crucial for achieving emissions reduction targets. However, this inevitably raises several issues stemming from the intermittency of wind as an energy source (Ahmed et al., 2020). Two system level solutions are available, the first is to increase the capacity of wind generation significantly beyond the maximum demand. This means that in periods of low wind energy, demand can still be met, however, this creates a significant increase in the levelised cost of wind energy. The second solution is energy storage, which can create additional demand when energy supply increases and provide energy when supply decreases. Thereby decreasing curtailment and lowering the total capacity requirement. Energy storage will play a major role in balancing less dispatchable renewable generation. At the distribution level of the energy system, homes and businesses with rooftop solar generation can avail of self-consumption, energy arbitrage, demand response and the opportunity to participate in the ancillary services market (Comello and Reichelstein, 2019). Furthermore, the effectiveness of solar technology can be enhanced by coupling it with battery energy storage systems. The penetration of small-scale distributed battery energy storage is expected to increase as battery-based technology investment becomes economically viable, with costs anticipated to decline as battery development advances (G ü nther et al., 2021).

In addition to dedicated battery energy storage systems, the electrification of transport is likely to influence the smart grid to a great extent. The penetration of electrified mobility in recent years has been phenomenal. As society is progressing from fossil fuel powered modes of transport to electric vehicles, which are charged using electricity derived predominantly from renewable sources (Liu et al., 2021). The battery storage capacity of EVs, when integrated into smart energy systems can be used as a demand response load when charging, and as a source to provide ancillary services such as frequency regulation and voltage support when discharging (Al-Obaidi et al., 2020). This EV-to-power system integration is a techno-economic arrangement known as 'vehicle-to-grid' (V2G), which enables the bidirectional flow of electricity between the EVs and the grid (Bibak and Tekiner-Mo ğ ulko ç, 2021). V2G is considered important for grid stability and flexibility, especially as the energy system becomes increasingly decentralised (Lund and Kempton, 2008). Therefore, it is crucial that the supporting power system infrastructure and retail market mechanisms are promptly and rigorously implemented, or electric vehicles will have the capability to strain the power system (Arias-Londo ñ o et al., 2020).

For a dynamic smart grid infrastructure to reach it's potential, emphasis is being placed on cross-linking energy industries and developing smart energy markets. Smart energy markets are an evolving market design where each energy sub-sector market (e.g., electricity, heating and cooling, refined liquid petroleum products or natural gas) is integrated into a broader energy market (Sorkn æ s et al., 2020). Focusing on how each sub-sector may complement each other is considered as an essential element for the development of economical solutions for 100% renewable energy systems (Lund). Heating and cooling networks are one such industry which is a prime candidate for sector coupling. Heating and cooling networks, traditionally fed by centralised fossil fuel generation plants, can be utilised to harness energy from large-scale renewables as well as small-scale excess heat driven prosumers. While the idea of consumers producing heat to be fed back into the network is plausible, some dynamical challenges exist with respect to supply temperature, differential pressure and pipe velocity. Current state-of-the-art research considers market-based solutions to such technical challenges in fourth-generation district heating systems, for example, tariffs which depend on the supply temperature (Lund et al., 2022). Customer owned roof mounted solar collectors and micro combined heat and power units are some of the distributed generation methods allowing consumers to become prosumers (Brown et al., 2019).

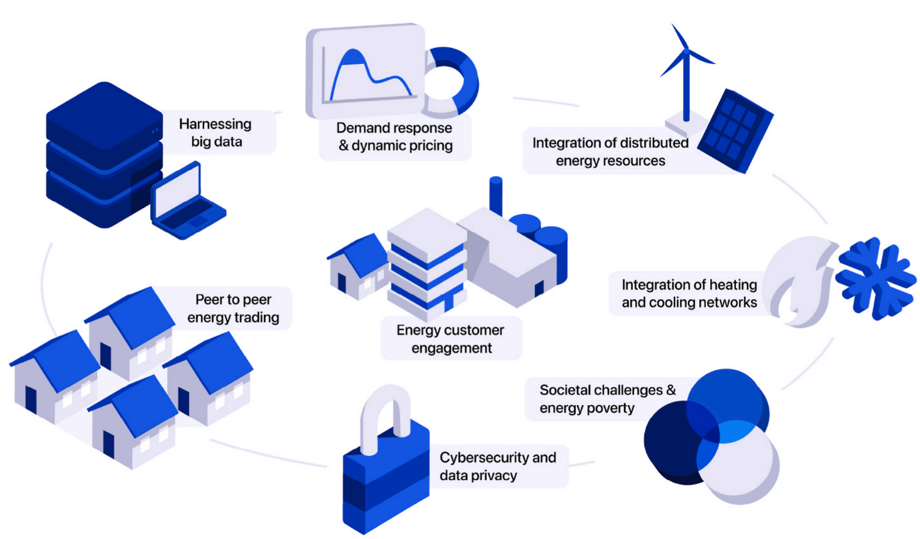

Fig. 1. Customer-centric focus in the smart grid. Source: Authors.

3. Embedding customer-centric energy policy

Historically, the adoption of customer-centric energy policy has been successful at addressing the energy user's requirement of a secure and affordable electricity supply (Haar, 2021). For example, in the United Kingdom and other regions, the electricity sector was radically reformed and modern retail electricity markets emerged. This was a consequence of liberalisation which commenced in the late 1990s, which led to monopolies separated into constituent parts, enabling free competition between energy retailers and between wholesale generators. In essence, liberalisation increased the number of market actors by dividing up vertically integrated utilities to create individual entities which are typically owned and operated by different companies (i.e., generators, transmission system operators, distribution network operators, network asset owners and energy retailers) (International Energy Agency, 2005).

Liberalisation of the energy sector has benefited the consumer; however, the process was initiated for a multitude of reasons depending on the jurisdiction. Europe asserted that regulation would promote a more efficient energy system and competition would reduce electricity prices. Political reasoning was also used, particularly in England, as the country argued that state-involvement in the energy system should be restricted. Moreover, in developing countries, deregulation was deemed a requirement as resource scarcity prevented funding of a vertically integrated energy system (Gencer et al., 2020). While deregulation and privatisation of the energy sector was successful in many ways, there is still a deficiency in the provision of systems to manage and promote customer engagement (Poudineh, 2019). Thus, there is an evolving necessity for further customer-centric energy policy to be implemented regarding the structure and operation of future retail electricity market design which supports vastly increased levels of customer engagement.

A customer-centric approach will combat the engagement deficiency in the retail electricity market by assessing consumer requirements, applying principles of behavioural psychology and encouraging optimal market participation. The ideal scenario will be that energy customers will endeavor to actively seek out the best energy deals from an economic and carbon footprint reduction perspective and commit fully to dynamic pricing arrangements.

Retail electricity markets have observed some optimistic improvement regarding customer engagement. In Great Britain, an Office of Gas and Electricity Markets (Ofgem) survey highlighted that 49% of consumers claimed to have engaged in energy supplier switching related activity (comparing or switching pricing arrangements) in 2019, a significant increase of fifteen percentage points since 2015 (Ofgem, 2020). In Ireland, the Commission for Regulation of Utilities (CRU) stated in a 2019 survey report that "if customers are aware of their consumption and cost thereof, they will be more likely to appreciate the value of a smart meter in enabling them to manage these aspects of their domestic and business affairs," page 5, (CRU, 2019). Thus, from the same survey report, CRU found that 75% of small and medium-sized enterprises (SMEs) participating in the retail electricity market indicated an interest in having a time-of-use tariff. Furthermore, the ability to view daily electricity usage appealed to 85% of SMEs (CRU, 2019).

An enhanced standard of customer engagement can be achieved by employing innovative energy marketing methods. Retail electricity markets facilitate the efficient exchange of electricity and natural gas. Consequently, over the last decade most British energy providers have elected to offer both products to consumers, usually by way of enticing discounted dual fuel tariffs. Moreover, retail energy companies have diversified their products by 'bundling' with other utilities (Furszyfer Del Rio et al., 2020), for example, Ovo Energy's fibre broadband internet & energy bundle ("Ovo Energy). Another innovative marketing method is a new pricing arrangement known as 'green' energy tariffs, which have developed as consumers become increasingly aware of their carbon footprint. One recent example is Octopus Energy's 'Fan Club' tariff which reduces the electricity price charged to their customers as wind speeds increase. However, this tariff is only available for those customers who live close to Octopus Energy operated wind farms (Octopus Energy and [Online]., 2021).

Smart meters are a crucial enabler of active customer engagement, as customers become physically integrated to the smart grid. Favourable reasons for the adoption of smart meters include real-time energy usage monitoring, time-of-use tariffs and financial incentives derived from demand response programs. However, to fully understand the implications of transitioning to a remarkably interconnected future, it is imperative to comprehend the potential cybersecurity and privacy risks which may arise. Four of the most prevalent privacy risks include: 1. Inference of sensitive information, 2. Discriminative customer segmentation, 3. Multi-person data and 4. Data aggregation (V é liz and Grunewald, 2018). It is clear that the mass deployment of smart meters needs to be carefully orchestrated to ensure that robust distributed networks are established and protective measures are put in place to mitigate cybersecurity and privacy risks.

As the installation of DERs (i.e., self-generation, demand response, electricity storage and power control systems) in homes and businesses propagates throughout the distribution level of the power system, the relationship between the customer and the electricity retailer is evolving (Abdelmotteleb et al., 2018). Technology such as DERs, smart meters and energy management software applications have enabled electricity customers to nergyi their individual energy consumption profiles and, subsequently, nergyi electricity bills according to their selected flexible tariff structure (Saumweber et al., 2021). In this context, the energy consumer experience will be nergyionized, with the introduction of smart meters and dynamic pricing arrangements which enable control of energy usage, management of expenditure and access to prosumer opportunities.

Present day British retail pricing arrangements are primarily comprised of the wholesale cost of electricity, environmental and social obligation costs, operating costs and network costs (Fig. 2) (Ofgem, 2021). However, while it is essential that all these costs are compensated, innovative retail pricing structures must establish a near real-time

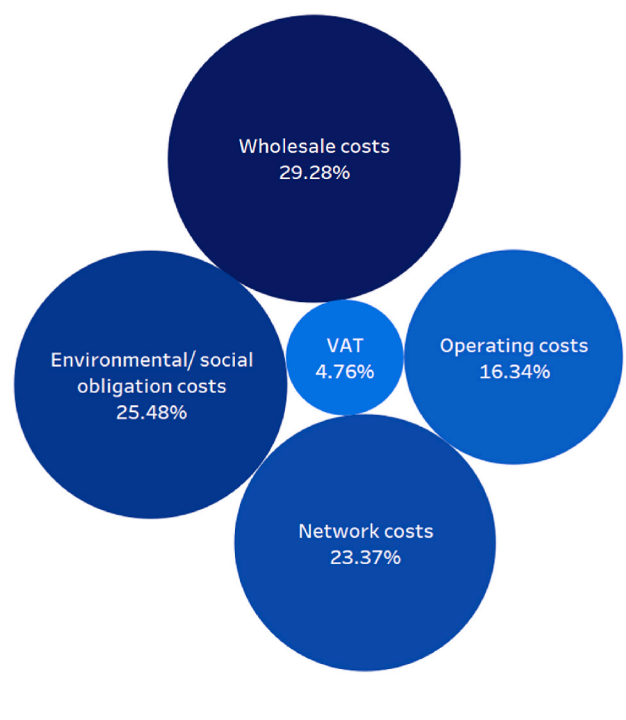

Fig. 2. Breakdown of 2020 annual electricity bill in Great Britain. Source: ("Infographic: Bills, 2021), compiled by Authors
Note: 'Other direct costs' (2.09%) and 'Supplier pre-tax margin' (−1.32%) excluded from figure.

link to the wholesale price of electricity (which is the key variable constituent of a typical energy bill). Even though, historically, consumers have been shielded from volatile wholesale electricity price intra-day fluctuations by the fixed nature of typical tariffs. This retail-wholesale price link is crucial, especially since one of the key indicators to assess retail electricity market efficiency "is the pass-through of upstream (wholesale) costs to downstream (retail) prices" page 230, (Mulder and Willems, 2019).

Smart electricity tariffs are an essential component of the customer-centric approach. These types of tariffs operate in combination with smart meters and energy management systems. Some smart electricity tariffs reflect temporal variation (e.g. time-of-use, real-time-pricing or critical-peak-pricing (Grimm et al., 2021)) in the price per kilowatt-hour, lowering cost of supply for consumers who respond by reducing or reallocating their consumption (Burns and Mountain, 2021). Furthermore, these time-varying tariffs exhibit a strong retail-wholesale electricity price relationship, as the price signals issued to consumers considers the real-time wholesale electricity price and current network status, regarding grid constraints and congestion (Soares et al., 2020). Other smart electricity tariffs include export tariffs (i.e., feed-in tariffs), tariffs which support direct load control (where an energy supplier requests operational control of certain household appliances for a finite period (Yilmaz et al., 2020)) and 'green' energy tariffs (which are specially designed pricing arrangements where the energy retailer guarantees that a proportion of the electricity supplied is derived from renewable energy generation (Diaz-Rainey and Tzavara, 2012)).

4. Supporting communities in the energy transition

Energy transitions are complex in nature and require profound revision of energy policy, actor relationships, financial exchanges and regulatory mechanisms (Sovacool and Geels, 2016). The current energy transition is driven by energy policy as society forges a path toward a net-zero carbon energy supply by the second half of the century, evading present day fossil-fuel dominance (Blazquez et al., 2020). Thus, there is an undeniable urgency to progress to an energy system consisting of low-emission, high-efficiency technologies while simultaneously benefiting from the economic stimulus accompanying this transition. However, distributional problems may arise across society unless appropriate arrangements are established to ensure an equitable and just transition. Leading to some individuals, communities or businesses being burdened more than others (Carley and Konisky, 2020).

Regardless of the promising opportunities provided by active customer engagement, there are some challenges to overcome. For instance, societal legitimacy and institutional trust are essential for users to engage in new business models and not to be locked out from emerging energy services (Hall et al., 2021a). Trust is not the only element that could exclude energy users, but since most of these services are enabled by being digitally connected, low-income households, vulnerable groups and rural households with a poor internet connection might as well be excluded from these nascent markets (Sovacool et al., 2021). Thus, we need to ensure that the transition towards a smart energy system does not leave anyone behind.

The embedment of customer engagement into energy markets needs to occur as part of an equitable low-carbon transition. Energy poverty is a further constraint on the decarbonisation optimisation problem; facilitating a 'Just Transition' will not only alleviate the plight of the vulnerable, but is also a necessity to maintain the social license of corporations and indeed governments to operate in energy markets (Robins and J, 2019). Within this context, we postulate that increasing positive consumer engagement, is in the interest of not only corporate profits but additionally household budgets, especially in a future where the systems which provide electricity and heat are more closely linked, and thus the risk of disconnection is amplified.

5. Embracing peer-to-peer transactive technology

The current energy system is moving towards a future where people can buy what they need and can sell when they have excess (Tushar et al., 2020). The application of transactional technology such as blockchain has led to the emergence of the P2P energy market concept, which is based on customer-to-customer business models and permits prosumer trading activity. Thus, P2P energy trading platforms are a potential vehicle for the widespread proliferation of DERs and network flexibility.

To ensure customer-centricity in future retail electricity markets, it is paramount to assess the customer's needs. Naturally, the primary need is that customers require an uninterruptable energy supply at low cost. However, as society progresses, there are other significant needs that the retail electricity market has an opportunity to fulfil, such as 'energy choice.' The current retail electricity market structure that is established in many countries, provides customers with limited choice of energy providers or the freedom to choose different types of energy services (Chen and Wencong, 2019). However, the uptake of DERs is propagating in many provinces and the opportunity to expand energy choice is far-reaching considering the vast potential for prosumer activity. However, the majority of prosumers with surplus energy can only exchange with energy retailers via dedicated feed-in tariffs (i.e., business-to-customer models). Therefore, prosumers may not achieve the best price for their energy and this is where customer-to-customer based models (e.g., peer-to-peer energy trading services like Piclo in the United Kingdom (Piclo, 2022)) become an important factor.

The term transactive energy relates to the use of economic mechanisms and control services that maintain the stability of the wider system (The GridWise Architecture Council, 2019). Thus, a P2P platform adopts the concept of transactive energy to enable prosumers to trade with energy consumers and other prosumers. The core transactive technology to enable P2P energy trading is currently available and is known as 'Blockchain.' Blockchain technology is a distributed computing paradigm which can create a reliable trading environment without a centralised authority (Moghaddam and Leon-Garcia, 2018). How P2P markets will be regulated and how this powerful technology is harnessed within existing retail electricity market structures will be of prominence in upcoming research. However, it is envisioned that P2P energy trading will only be a feature of the future retail electricity market structure. Especially since innovative energy business models, such as P2P energy trading, is currently only attractive to the most engaged customers (Hall et al., 2021b). The future retail market design will ensure customer centricity by integrating peer-to-peer transactive technology, implementing robust dynamic pricing arrangements and address the societal and distributional impacts of the energy transition.

6. Conclusion

Our perspective discussed the key concepts for developing future retail electricity markets with a customer-centric focus. We postulated that a customer-centric approach will maximise customer engagement, optimise the utilisation of smart grid technologies, heighten renewable energy deployment and promote network flexibility. As such, we explored the following topics: the changing energy infrastructure landscape, embedding customer-centric energy policy, supporting communities in the energy transition and embracing peer-to-peer transactive technology. Moving forward, this short communication provides a knowledge-base for energy system policy makers and stakeholders for decision-making and future market design.

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CRediT authorship contribution statement

Harrison Hampton: Conceptualization, Methodology, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration. **Aoife M. Foley:** Conceptualization, Methodology, Data curation, Formal analysis, Investigation, Writing – original draft, Writing – Reviewing and Editing, Funding acquisition. **Dylan Furszyfer Del Rio:** Writing- Reviewing and Editing. **Benjamin Sovacool:** Conceptualization, Writing- Reviewing and Editing.

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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References

Abdelmotteleb, I., Gómez, T., Ávila, J., Reneses, J., 2018. Designing efficient distribution network charges in the context of active customers. Appl. Energy 210, 815–826.
Ahmed, S.D., Al-Ismail, F.S.M., Shafiullah, M., Al-Sulaiman, F., El-Amin, I., 2020. Grid integration challenges of wind energy: a review. IEEE Access 8, 10857–10878.
Al kez, D., Foley, A.M., McIlwaine, N., Morrow, D.J., 2020. A critical evaluation of grid stability and codes, energy storage and smart loads in power systems with wind generation. Energy 205, 117671.
Al-Obaidi, A., Khani, H., Farag, H.E., Mohamed, M., May 2020. Bidirectional smart charging of electric vehicles considering user preferences, peer to peer energy trade, and provision of grid ancillary services. Int. J. Electr. Power Energy Syst. 124, 106353, 2021.
Arias-Londoño, A., Montoya, O., Grisales-Noreña, L., 2020. A chronological literature review of electric vehicle interactions with power distribution systems. Energies 13, 3016.
Bibak, B., Tekiner-Moğulkoç, H., 2021. A comprehensive analysis of Vehicle to Grid (V2G) systems and scholarly literature on the application of such systems. Renew. Energy Focus. 36, 1–20.
Blazquez, J., Fuentes, R., Manzano, B., 2020. On some economic principles of the energy transition. Energy Pol. 147, 111807.
Brown, D., Hall, S., Davis, M., 2019. Prosumers in the post subsidy era: an exploration of new prosumer business models in the UK. Energy Pol. 135, 12.
Burns, K., Mountain, B., 2021. Do households respond to Time-Of-Use tariffs? Evidence from Australia. Energy Econ. 95, 105070.
Carley, S., Konisky, D.M., 2020. The justice and equity implications of the clean energy transition. Nat. Energy 5, 569–577.
Chen, T., Wencong, S., 2019. Indirect customer-to-customer energy trading with reinforcement learning. IEEE Trans. Smart Grid 10.
Comello, S., Reichelstein, S., 2019. The emergence of cost effective battery storage. Nat. Commun. 10 (1), 1–9.
CRU, 2019. Findings from 2019 Research on Attitudes and Experiences in the Domestic and SME Electricity and Gas Markets in Ireland. Dublin.
Davis, S., Lewis, N., Shaner, M., 2018. Net-zero Emissions Energy Systems. AAAS Science.
Diaz-Rainey, I., Tzavara, D., 2012. Financing the decarbonized energy system through green electricity tariffs: a diffusion model of an induced consumer environmental market. Technol. Forecast. Soc. Change 79 (9), 1693–1704.
Furszyfer Del Rio, D.D., Sovacool, B.K., Bergman, N., Makuch, K.E., 2020. Critically reviewing smart home technology applications and business models in Europe. Energy Pol. 144, 111631.
Günther, C., Schill, W., Zerrahn, A., 2021. Prosumage of solar electricity: tariff design, capacity investments, and power sector effects. Energy Pol. 152, 112168.
Gencer, B., Larsen, E., Ackere, A., 2020. Understanding the coevolution of electricity markets and regulation. Energy Pol. 143, 111585.
Gourisetti, S., Sebastian-Cardenas, D.J., Bhattarai, B., 2021. Blockchain smart contract reference framework and program logic architecture for transactive energy systems. Appl. Energy 304, 117860.
Grimm, V., Orlinskaya, G., Schewe, L., 2021. Optimal design of retailer-prosumer electricity tariffs using bilevel optimization. Omega 102, 102327.
Haar, L., 2021. The competitive disadvantages facing British assetless electricity retailers. Energy Pol. 155, 112323.
Hall, S., Anable, J., Hardy, J., 2021a. Matching consumer segments to innovative utility business models. Nat. Energy 6, 349–361.
Hall, S., Anable, J., Hardy, J., 2021b. Innovative energy business models appeal to specifc consumer groups but may exacerbate existing inequalities for the disengaged. Nat. Energy. Pol. Brief.
International Energy Agency, 2005. Lessons from Liberalised Electricity Markets. OECD/IEA, Paris, France.
Kanakadhurga, D., Prabaharan, N., 2021. Demand response-based peer-to-peer energy trading among the prosumers and consumers. Energy Rep. 7, 7825–7834.
Liu, Z., Song, J., Kubal, J., 2021. Comparing total cost of ownership of battery electric vehicles and internal combustion engine vehicles. Energy Pol. 158, 112564.
H. Lund, "Renewable heating strategies and their consequences for storage and grid infrastructures comparing a smart grid to a smart energy systems approach," Energy, vol. 151, pp. 94-102, 151.
Lund, H., Kempton, W., 2008. Integration of renewable energy into the transport and electricity sectors through V2G. Energy Pol. 36 (9), 3578–3587.
Lund, H., Østergaard, P.A., Connolly, D., Mathiesen, B.V., 2017. Smart energy and smart energy systems. Energy 137, 556–565.
Lund, H., Thorsen, J.E., Jensen, S.S., Madsen, F.P., 2022. Fourth-generation district heating and motivation tariffs. ASME Open. J. Eng. 1. AOJE-21-1029.
Moghaddam, M.H.Y., Leon-Garcia, A., 2018. A fog-based internet of energy architecture for transactive energy management systems. IEEE Internet Things J. 5.
Mulder, M., Willems, B., 2019. The Dutch retail electricity market. Energy Pol. 127, 228–239.
Octopus Energy, [Online]. Available: https://octopus.energy/press/blow-those-costs-away-octopus-energy-launches-worlds-first-electricity-tariff-that-gets-cheaper-when-its-windy/. [Accessed 23 01 2021].
Ofgem, 2020. Ofgem Consumer Survey 2019. London.
Ofgem, Costs in your energy bill," Ofgem, [Online]. Available: https://www.ofgem.gov.uk/energy-advice-households/costs-your-energy-bill. [Accessed 07 10 2021].
Piclo, "Piclo - an independent marketplace for flexibility services.," [Online]. Available: https://www.piclo.energy/. [Accessed 06 06 2022].
Poudineh, R., 2019. Liberalized retail electricity markets: what we have learned after two decades of experience? Oxford Inst. Energy Stud. OIES Paper: EL 38.
Robins, N., J, R., 2019. Why a Just Transition Is Crucial for Climate Action. UN Principles for Responsible Investment, London.
Saumweber, A., Wederhake, L., Cardoso, G., 2021. Designing Pareto optimal electricity retail rates when utility customers are prosumers. Energy Pol. 156, 112339.
Soares, I., Alves, M., Antunes, C., 2020. Designing time-of-use tariffs in electricity retail markets using a bi-level model – estimating bounds when the lower level problem cannot be exactly solved. Omega 93, 102027.
Sorknæs, P., Lund, H., Skov, I.R., 2020. Smart Energy Markets - future electricity, gas and heating markets. Renew. Sustain. Energy Rev. 119, 109655.
Sovacool, B.K., Geels, F.W., 2016. Further reflections on the temporality of energy transitions: a response to critics. Energy Res. Social Sci. 22, 232–237.
Sovacool, B.K., Furszyfer Del Rio, D., Griffiths, S., 2021. Policy mixes for more sustainable smart home technologies. Environ. Res. Lett. 16 (5).
The GridWise Architecture Council, 2019. The GridWise Transactive Energy Framework.
Tushar, M.H.K., Zeineddine, A.W., Assi, C., 2018. Demand-Side management by regulating charging and discharging of the EV, ESS, and utilizing renewable energy. IEEE Trans. Ind. Inf. 14 (1), 117–126.
Tushar, W., Saha, T.K., Yuen, C., Smith, D., Ashworth, P., 2020. Challenges and prospects for negawatt trading in light of recent technological developments. Nat. Energy 5, 834–841.
UK Government, "Energy White Paper, December 2020. Powering Our Net Zero Future. London.
Véliz, C., Grunewald, P., 2018. Protecting data privacy is key to a smart energy future. Nat. Energy 3, 702–704.
Yilmaz, S., Xu, X., Cabrera, D., 2020. Analysis of demand-side response preferences regarding electricity tariffs and direct load control: key findings from a Swiss survey. Energy 212, 118712.
Infographic: bills, prices and profits," ofgem, [online]. Available: https://www.ofgem.gov.uk/publications/infographic-bills-prices-and-profits. [Accessed 06 10 2021].
Ovo Energy's fibre broadband & energy bundle," [Online]. Available: https://sse.co.uk/phone-and-broadband.