Energy Research & Social Science 97 (2023) 102997

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

Fintech RE in a global finance centre: Expert perceptions of the benefits of and challenges to digital financing of distributed and decentralised renewables in Hong Kong

Laurence L. Delina

Division of Environment and Sustainability, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

ARTICLE INFO

Keywords:
Blockchain
Fintech
Digitalisation
Decarbonisation
Hong Kong
Green finance

ABSTRACT

Decarbonisation efforts at the decentralised and distributed level, such as solar photovoltaic or wind installations with storage in homes or buildings, can be funded through digital fintech instruments via, for example, peer-to-peer trading in a blockchain ecosystem. This financial innovation melds the energy transition agenda with the digital economy, delivering what can be called "fintech RE." This paper explores this innovation by focusing on expert perceptions from Hong Kong, a global financial centre envisaging to become a hub for regional and international green finance. Interviews involving respondents from three divergent industries – energy, digital technology, and finance – solicited expert perceptions of the likely impacts of this emergent innovation on Hong Kong and their respective industries. While interview data suggest potential benefits of fintech RE – particularly in terms of new opportunities for citizen participation in energy transition via a decentralised energy market, new jobs, and contribution to decarbonisation, this innovation also presents a challenge to the territory's distinct electricity market arrangement, the spatial issues with scaling and speeding energy transition in a dense environment, and its attendant emission pitfalls.

1. Introduction

> Creating a decentralised energy and power grid would increase the scope of all human innovation. I think over time, we will see solar grid electric, self-driving cars that will essentially be machines running and controlled and administered by blockchains. It will be decentralised. I think we are now in the direction of the Internet, that has gone from having lots of overly expensive middlemen to having a few middlemen, and now it is going to go to having no middlemen or just the absolute minimum. The Internet is going to become a giant grid.
>
> **- Naval Ravikant**, co-founder, chairman, and former CEO of AngelList, a US-based website for angel investors and start-ups [1].

As with other countries and territories, the Hong Kong government envisages contributing to the global decarbonisation agenda, including meeting the Sustainable Development Goals (SDGs) and the broader sustainability efforts. This special administrative region of China outlines its strategies to achieve carbon neutrality by 2050 in a document titled 'Hong Kong's Climate Action Plan 2050,' released in October 2021 [2]. The vision targets the year 2035, when Hong Kong will reduce its carbon emissions by half compared to the 2005 level, and the year 2050, when it achieves carbon neutrality. The city plans to do this by increasing the share of renewable energy in the fuel mix to 10 % by 2035 and 15 % while phasing out coal to achieve net-zero electricity generation by mid-century [3]. This transition is hinged on developing the city's renewable energy potential and strengthening regional cooperation on energy trade considering local resource constraints [3]. Complementary strategies to achieve this ambition exist through energy savings, greening buildings and transport, and waste reduction. Hong Kong, an international finance centre, also envisages becoming a green finance hub ([45]; cf. [5]). Both carbon neutrality and green finance visions, thus, open opportunities for developing new mechanisms, tools, and arrangements that could bridge actors working in the energy transition, finance, and digital industries. This paper looks at the amalgam of these presently siloed sectors exploring their potential impacts, in terms of the benefits and challenges, of what I termed "Fintech (renewable energy) RE."

Fintech RE offers an opportunity to transition energy systems towards more renewable and flexible arrangements. It does this by integrating RE generation units and storage, such as batteries, in a small-scale distributed system and using peer-to-peer energy trading

E-mail address: lld@ust.hk.

https://doi.org/10.1016/j.erss.2023.102997
Received 9 October 2022; Received in revised form 18 January 2023; Accepted 6 February 2023
Available online 15 February 2023

platforms in the digital environment [6,7,8]. These platforms make use of blockchain technologies, where energy transactions are conducted in virtual energy marketplaces [9,10]. This arrangement, thus, cancels the need for intermediaries (such as those in a conventional energy market), thereby increasing efficiency and improving transparency in a relatively more straightforward produce-buy-and-sell environment (cf. [11]; [9]). Fintech RE, in essence, is a bi-directional and digital peer-to-peer exchange between the renewable energy producer and the consumer using blockchain solutions.

Fintech RE is still in its infancy despite several pilot and demonstration projects worldwide. Gunaratha et al.'s [12] review of these schemes listed fifty extant peer-to-peer energy trading projects across scales: from the household to neighbourhoods to community to the city to national to regional network sizes, in both high and low-income countries, including Germany, the United States, the United Kingdom, Denmark, Australia, Japan, India, and Thailand, among others. Gunaratha et al.'s review [12] suggested that Fintech RE could offer a new opportunity for accelerating energy transitions while maintaining the proven benefits of distributed energy resources. These demonstrated benefits occur in terms of household savings due to reduced energy bills [13], local energy resilience from weather extremes [14,15], and contribution to climate mitigation by decarbonising the energy systems. All these ends contribute to meeting several SDGs, especially SDG7 on energy transition and SDG13 on climate action. As more distributed energy systems join the more extensive energy network, excess supply would require investments in small-scale renewable energy production equipment (comprising not only the generation systems, such as rooftop solar or wind but also storage and their attendant accounting and management systems). However, Fintech RE offers an alternative for prosumers in this new ecosystem to trade their excess renewable energy generation with their neighbour-consumers instead of sending it directly to the grid. This on-site produce-buy-and-sell arrangement means more efficiency as losses are reduced with electricity consumed close to where it is generated [16,17].

This paper uses social science approaches to investigate the promise of Fintech RE as an emergent technology. Situating it in Hong Kong's decarbonisation and green finance centre visions, the paper continues in Section 2 with a layout of the extant literature and the state-of-art, providing background information. Section 2.1 presents a review of the energy transition-financialisation-digitalisation triangle or Fintech RE. Section 2.2 reviews the contestations surrounding the possible impacts of Fintech RE on the derailment of decarbonisation efforts, given how bitcoin mining contributes to rising emissions. Section 2.3 introduces Hong Kong's distinct status as a financial centre, a special administrative region of China, and its unique electricity system and energy institutional arrangement. Section 3 presents this paper's principal research question and interview approach in primary data collection. Section 4 presents the results of interviews collected on the perceptions of key informants towards a future Hong Kong Fintech RE ecosystem. Sections 5 and 6 offer discussion and conclusion, opening opportunities for future research on this emergent innovation's policy, governance, and social studies.

2. Background: Fintech RE and the Hong Kong electricity market

2.1. How Fintech RE works: the energy transition-financialisation-digitalisation triangle

One crucial component of the energy transition is the financialisation of decarbonisation activities. In this context, financialisation refers to funding support to deploy renewable energy systems across scales. Driving and accelerating the disbursements of financial capital by attracting investors remains necessary for accelerating energy transition and decarbonisation. As distributed energy generation proliferates at the micro-scale, that is, at households, buildings, communities, and neighbourhoods (e.g., [18,19]), designing financial instruments that can support and sustain these systems become paramount. Distributed energy systems have become more critical as the transition transforms conventional electricity consumers at the household level into prosumers with rooftop solar or wind installations [20].

However, conventional grids may not be able to sustain the increasing volume of new energy generation as more prosumers begin exporting their excess renewable energy. An on-site produce-buy-and-sell approach, thus, offers a potential solution. In this arrangement, renewable energy generators, that is, the prosumers, would trade their excess electricity with other consumers in a small network [20,21,22]. For this approach to function, advances in smart grid operations, storage systems, and demand management have become necessary [23]. Fintech RE also comes into the picture as a digital mechanism facilitating produce-buy-and-sell transactions between and among network members while offering increased transparency and security simultaneously (e.g., [24]).

These peer-to-peer projects have been demonstrated in practice in several examples and locations (e.g., [25,26]; see [12] for a review of these projects). Digitalisation exists in peer-to-peer trading using ICT-based platforms, where virtual markets are created in parallel to the physical distribution of renewable energy supply. Digitalisation further decentralised the energy system beyond generation to cover energy distribution transactions. The absence of a central authority or institutional arrangement, such as an electric utility, means that this configuration must provide maximum security, privacy, reliability, affordability, and trustworthiness. This paper focuses on the role of blockchain, an ICT-based platform, in meeting these conditions in this new electricity and finance ecosystem.

Blockchain is a database that records data in a chain structure. It does this by combining data blocks in sequential order. Blockchain relies on cryptography to ensure that this digital and distributed ledger is safeguarded with counterfeit-proof data [27]. Because of these characteristics, blockchain, thus, opens opportunities for secure and trustworthy energy trading platforms.

In addition to its potential use in peer-to-peer platforms, blockchain could also assist renewable energy utilities, suppliers, consumers, and prosumers in managing energy distribution across more extensive networks and in reducing grid peak load [28,13]. Blockchain's offering in the supply-and-demand management system could help prevent energy shortages during peak hours from the utility side and reduce electricity costs on the consumer side. Blockchain can also open opportunities for electric vehicle charging and smart device connection. Electric vehicle users may use blockchain as a platform to make energy transactions through sharing chargers powered by solar energy, which helps automatise the payment process, build confidence in peer-to-peer trading, reduce peak load hours for charging, and ensure data privacy [29]. As demands for charging increase, blockchain could help ensure sufficient charging facilities for electric vehicle users. Blockchain could also provide a reliable system for carbon tracking for the net-zero economy and create energy production source certificates in carbon markets [30]. Here, blockchain could be used as a platform to verify emission rights and process the trading of carbon credits [31]. Because of their trustworthiness and security features, blockchain-based certificates could guarantee that energy is produced from renewable energy sources [32].

One example of Fintech RE is in the borough of Brooklyn in the City of New York. Siemens partnered with a start-up, "LO3 Energy," in developing a produce-buy-and-sell ecosystem with blockchain characteristics [26,33,34]. Brooklyn residents with access to rooftops put up solar PV systems. Using blockchain-enabled peer-to-peer trading, they would then sell their excess solar energy to their neighbours in the same produce-buy-and-sell ecosystem. This digital bookkeeping system allowed those without solar PVs to buy solar electricity directly from this on-site electricity system rather than from the grid [26,33]. This system connects smart meters with computers that measure solar energy

generation that is then shared between and among neighbours in the blockchain. The blockchain performs as a shared ledger, where it groups energy trades/transactions into blocks linked in a chain, which are then verified. These transactions have since expanded to neighbouring communities with ambitions to use this model to sell energy legally across the entire state of New York [26,33].

The Brooklyn produce-buy-and-sell ecosystem is one of the many examples documenting the practicality of Fintech RE (see [12] for a detailed and most recent list and descriptions). As other cities, territories, and countries envisage deploying similar tools to support the funding of their accelerated energy transition, little is known, however, about how Fintech RE could impact decarbonisation efforts. How extant financial systems, electric markets, and regulatory arrangements could respond to this innovation is little known. While these factors are least known at present, the potential stress this innovation could bring to the electricity network and how it could potentially derail decarbonisation efforts have been rigorously studied. I turn into these issues next.

2.2. Fintech RE poised to pressure the electricity network and increase emissions

Fintech RE has notable challenges. It is a double-edged sword. While this innovation seems promising, as discussed in 2.1, the literature also points out that blockchain-related pollution could easily and quickly counter the benefits of a supposed energy transition. There are two contentious yet related impacts identified: the pressure on the electricity network since transaction verifications (or crypto mining) require substantial amounts of energy, and, consequently, increasing emissions, especially when the energy used for mining is from carbon-based power plants [35,36,37,38].

Digital currency transactions have become more efficient primarily due to computing power and technical hardware advances. However, energy consumption and their resulting emissions – especially for protocols using proof-of-work (PoW) mechanisms – have also increased overall [36,37]. PoW blockchain is the most common verification protocol, but it requires energy-intensive mining procedures to verify digital trades [38,39]. Rewards are "paid" in cryptocurrency, such as bitcoins. It is where miners make money. The environmental risks from PoW stem from this protocol since verification needs multiple energy-intensive devices to process. Unless PoW machines are in places serviced by 100 % renewable energy systems, this protocol subjects electricity grids to stress and, consequentially, increases carbon emissions.

Less-polluting consensus protocol alternatives to PoW blockchains exist. Some examples include proof-of-stake (PoS) and proof-of-authority (PoA) protocols. Unlike PoW, which requires multiple verifiers, PoS blockchain, for instance, requires only a single validator to complete verification. This means the machines needed in mining would be minimal in number compared to a PoW system. However, these alternatives are less attractive to miners since most platforms would prefer their tried-and-tested PoW protocols, which are considered the industry standard and have more proven security [37].

Operating digital currency transactions that use high polluting PoW protocols pose risks to the decarbonisation agenda. Blockchain platforms, thus, should be encouraged to move out of their PoW lock-in and path dependency. Internalising these risks via policy and regulations to reduce emissions related to digital transactions, thus, is needed. Truby et al. [37] listed some of these policy interventions, which included: (1) switching away from PoW blockchain towards more efficient and less-polluting protocols, (2) discouraging PoW by introducing sales or income taxes based on their energy use or charging high-volume users a premium on their energy bills, and (3) regulating against PoW by halting these verification methods altogether.

One would readily notice how these interventions increase in their stringency as they are proposed. The latest of them, i.e., closing PoW authentication methods to validate blockchain transactions, has been demonstrated in China and is proposed in the Senate of the State of New York as of this writing. In both jurisdictions, the reason for halting PoW methods is related to the pressure they brought upon the electricity networks and their tendency to derail decarbonisation advances. For these reasons, China has prohibited the provision of services related to digital currency transactions, including by financial institutions, since May 2021 [40]. The Senate of the State of New York also passed similar legislation but provided an option to PoW-authenticated blockchains operating in the state by requiring them to conduct environmental impact assessments; otherwise, they risk closure [41].

The Chinese case illustrates the ability of direct regulation, in this case, a halt on PoW-based mining, to reduce emissions from digital currency work at the national level [42]. However, this method proved less effective in reducing global emissions from digital transactions since many miners had simply relocated their activities to countries without such legislation, such as Kazakhstan and Iran [43,44]. PoW miners were offered affordable energy supply in these new locations, and their activities were conducted with limited to zero regulations [37]. This means that while China's crypto emissions had lowered, these were simply transferred. The risks of carbon emissions leakage, thus, are high in digital currency transactions, especially in the absence of an international strategy for addressing it.

Having discussed Fintech RE and its potential in derailing decarbonisation efforts, I now provide a background to this paper's case study. The following subsection describes Hong Kong's ambition of becoming a regional and international hub for green finance, its distinct electricity market, and the new opportunity for introducing Fintech RE in the city's local electricity system.

2.3. Hong Kong as a global green finance hub, its unique electricity market, and Fintech RE's potential in the city

Hong Kong, a special administrative region of China, is home to about US$ 3.7 trillion in assets under management, making it Asia's number one international fund management hub [4]. Hong Kong's financial service sector in 2019 comprised US$ 4.14 trillion in banking assets [4]. Its stock market, with a market capitalisation close to US$ 5 trillion, is the first in the world in terms of IPO fundraising [4].

In addition to being a global financial centre, Hong Kong seeks to become a regional, Asian, and international hub for green finance [4]. The city's climate action plan and vision to become carbon neutral by 2050 provide Hong Kong with the basis to position itself as an active driver of energy transitions. Hong Kong could achieve this by providing much-needed funding for the decarbonisation of energy systems in the city, the region, Asia, and internationally. Fintech RE, thus, could appeal to Hong Kong since it could support the global energy transition agenda and, at the same time, deploy this innovation locally to meet the city's own carbon neutrality ambition. This paper focuses on the potential of Fintech RE being deployed in the city while also acknowledging Hong Kong's unique electricity system. The latter could pose a challenge for the scaled deployment of Fintech RE innovation in the city.

Hong Kong is among the few territories and cities in the world with a guaranteed affordable, secure, and reliable electricity supply. Regulations ensure these qualities by entrusting only two utilities to provide electricity in the territory. The first of these utilities is China Light and Power (CLP), which supplies about 80 % of the Hong Kong population in Kowloon, the New Territories, and outlying islands. The second is Hong Kong Electric (HK Electric), which services the remaining 20 % of the city in Hong Kong Island and Lamma Island. Both electric utilities generate, import, and distribute electricity, operating in what could be considered a monopoly market.

Despite Hong Kong operating in a free market system, most public services – including electricity – remain highly regulated. This means that the territory's electricity market, unlike in other free economies (such as those in Australia, Europe, the United Kingdom, and the United States), is government controlled. The Hong Kong government

established control via Schemes of Control which began in 1964. These are bilateral agreements that the two power companies agreed with the Hong Kong government. Although the electricity sector is privately owned, managed, and operated, the government monitors their performance and financial affairs via these agreements. The Schemes of Control oblige the two power companies to supply Hong Kong with sufficient, reliable, and affordable electricity to their respective service areas.

To promote renewable energy in Hong Kong, CLP and Hong Kong Electric buy RE certificates and provide feed-in tariffs (FiT) to installers of renewable energy systems which connect them to the grid. Business customers can buy RE certificates at a price published by their respective utility. Launched in May 2018, the city's FiT scheme supports RE systems below 10 kW capacity at rates between HK$ 2.5 to HK$ 4 per kWh as of this writing [46,47]. The rates are reviewed regularly. Despite the availability of these support policies, the contribution of renewable energy to Hong Kong's energy mix remains substantially low at only 0.11 % [48]. Even with the FiT scheme, maximising the city's renewable energy potential – particularly solar – remains a pipeline dream [49,50]. The city's solar potential alone is projected to supply some 10 % of the demand [51], with more optimistic scenarios, including a 100 % renewable Hong Kong, suggesting the city's 2050 energy demand for electricity, transport, and other services could be met entirely by renewable energy, with offshore wind contributing the largest (cf. [52]).

Considering Hong Kong's standing as an international finance centre, its vision to become a hub for green finance, and its potential for generating local renewable energy, Fintech RE offers opportunities for the city and its residents. As mentioned in Section 2.1, Fintech RE could bring several benefits in making energy systems more efficient and resilient due to their distributed nature and promise as an investment tool. However, Fintech RE also presents new challenges. As mentioned in Section 2.2, most of these issues are related to blockchain's emissions contribution. Little is known, however, concerning these impacts as they pertain to Hong Kong and as perceived by the city's key stakeholders. This paper addresses some of these gaps.

3. Research questions and methods

3.1. Research question

This study's principal research question is how actors and experts in Hong Kong's finance, digital technology, and energy sectors perceive the blending of the digital, Fintech, and renewable energy sectors or what we term Fintech RE in support of decarbonisation. Specifically, it is focused on knowing more about the impacts in terms of the possible benefits and challenges of this innovation to Hong Kong as an international finance centre and to its residents. The study asked: How could Fintech RE impact the city's decarbonisation efforts, extant financial systems, electric markets, regulatory arrangements, residents, and electricity consumers? This study is anticipatory and future-oriented since the integration of Fintech RE into Hong Kong's electricity system and its electricity consumers are still in the envisaged future.

3.2. Methods: expert elicitation

The research – which explores a new topic area (i.e., Fintech RE in Hong Kong) where little previous research has been conducted – adopted a grounded theory approach to generate theory from data [53]. Data was collected using key informant interviews or expert elicitation employing a semi-structured interview guide. These interviews flowed in a conversational technique, allowing deviations beyond the original question to explore further directions inherent in the grounded theory approach [53]. The interview guide comprised the following questions: (1) what comes to mind when you hear "Fintech and renewable energy." The interviewee would then ask follow-up questions focusing exclusively on the Hong Kong context: (2) what the benefits of this innovation to Hong Kong could be; (3) what the challenges could be; (4) what areas in the city's economy and governance need to change to suit this innovation, and (5) what strategies can be done to facilitate these shifts. The Human Research Ethics Protocol (HREP) of this study was approved by the Hong Kong University of Science and Technology HREP committee on February 2, 2021 (Protocol No. 602).

To attract participation, potential interviewees from the author's network in Hong Kong's finance, energy, and digital technology sectors were sent invitation emails. The research approach does not seek to elicit representative perceptions, which is impossible given the universe of Hong Kong's finance, digital technology, and energy actors. At the time of the interviews, all respondents worked in one of the three sectors mentioned. Potential biases in the methodology were addressed by adopting several approaches. Selection bias, for example, could occur, considering that recruitment begins from a select group of people. This potential bias was addressed via a snowball approach. After the interview, respondents were asked to suggest who could be interviewed next. This opened the study to more participants beyond the author's original network.

The interviews lasted 40 min on average, with some extending up to 90 min, and were conducted on Zoom in July and August 2021. The respondents were shown slides containing the questions to guide the Zoom conversations. Some of these slides provide some definitions and examples of concepts that were less familiar to the interviewees. For example, Fintech RE was defined and described with the Brooklyn example discussed in 2.1. A definite set of questions, worded the same across interviews, reduced the potential of variable questioning bias.

The respondents were sent a consent form ahead of the interview date. They were asked for their consent again at the beginning of the interviews. The recordings were first transcribed using the software otter.ai and were manually cleaned and validated. Data collection was concluded upon saturation when the latter respondents began regurgitating what had already been shared by earlier interviewees (cf., [54]). Altogether, eighteen experts provided data for this research (see Table 1 for their basic profiles).

The qualitative data collected from interviews were coded using

Table 1
Expert codes and brief profiles.

Expert codes	Profile
E01	A senior management-level professional and a postgraduate student studying ESG and finance in Hong Kong
E02	A professor of energy studies with expertise in energy investments in Asia
E03	A professor of public policy with expertise in data science
E04	A professor of sustainability with expertise in sustainability reporting
E05	A professor of energy studies with expertise in Hong Kong's energy sociotechnical systems
E06	A director of an engineering and business firm providing services for various projects, including energy
E07	A professor of practice in Fintech and accounting
E08	A manager of a Hong Kong-based NGO that is focused on Fintech
E09	A director of a research department in an electricity company in Hong Kong
E10	A manager of a public policy think tank that focuses on climate change
E11	A senior environmental protection officer at the Hong Kong Environmental Protection Department
E12	A director at a consulting firm focusing on ESG, green finance, and sustainability
E13	A consultant and an engineer with portfolios in the energy and the environment
E14	A managing director at a consulting firm with clients in the energy industry
E15	A founder and chief executive of an NGO working on environmental conservation
E16	A consultant at the International Renewable Energy Agency
E17	A director of an investment company with portfolios in Singapore and Hong Kong
E18	A manager of a financial services company in Hong Kong

MAXQDA, a specialised software for analysing textual data. The author's research assistants peer-reviewed the codes to ensure high quality. Data analysis followed a three-round coding protocol consistent with the grounded theory approach. First, the data was coded by identifying recurrent information on the impacts of Fintech RE. Then, these codes were described as to whether these impacts could be a benefit or a challenge. Finally, these benefits and challenges were arranged in order of their recurrence. The following section presents the results.

4. Results: expert perceptions of the benefits and challenges of Fintech RE to Hong Kong

4.1. Perceived benefits

4.1.1. To Hong Kong: elevating Hong Kong's position as a green finance hub by promoting Fintech technologies and decarbonisation simultaneously

Fintech RE could open the door to more investments in Hong Kong. The innovation could also help Hong Kong reassert its position not only as a centre for international finance but also as an emerging green finance hub. Hong Kong can use Fintech RE in reorienting private capital to sustainable investing and manage financial risks due to climate change.

Fintech RE fits the agendas of many countries pledging to peak their emissions and achieve carbon neutrality goals. E03, for instance, mentioned that Fintech RE could be used to promote the development of locally developed and applied Fintech technologies while expanding the application and integration of renewable energy in the city. E03 saw this combined value, suggesting that harvesting the benefits of the energy transition could go together with the government stimulating investments and arousing the interest of electricity users and investors, viz.:

> Applying Fintech to renewable energy is a win-win situation for all stakeholders. It will help to promote the development of Fintech not only in Hong Kong but worldwide. Fintech will attract interested parties to make more renewable energy investments. By stimulating investments, both Fintech and RE technologies will improve. Fintech RE will also arouse the interest of end users, that is, the public, to use renewable energy. This innovation can lead to more investments, stimulating research into green investment products (E03).

4.1.2. To the public: opening opportunities for public participation in energy transactions by simulating new investment platforms and creating new jobs and businesses

Fintech RE promotes prosumerism and empowers individuals with their energy choices. E08 perceived Fintech RE as an enabler for the public to eventually choose from various electricity providers, which is currently absent in Hong Kong's energy system. By opening the city's energy market to blockchain-based RE trading, individuals would be empowered to choose the energy generation company they want to meet their electricity demand. Fintech RE also enables consumers to evaluate the pros and cons of each energy provider available to them.

Hong Kong's existing feed-in-tariff scheme for installations below 10 kW is a step towards energy transition in the city; E08, however, suggested that this scheme fails to stimulate investments, saying:

> We have feed-in tariffs in Hong Kong but selling them has not been easy. People are not installing solar PV because they will make money from it. They are putting solar PV for its green attribute. Yet, the green attribute itself is not very popular (E08).

By using platforms that blockchain technologies offer for energy trading, one can benefit from investing in them. E08 also suggested Fintech RE could offer the public a new investment opportunity, allowing end users to participate in energy trading using blockchains. E04 was particularly interested in the potential of a local energy trading platform for electricity, saying:

> Perhaps, we can have a local trading platform for electricity, and then we can get benefits, earn money, and make a whole new change in lifestyle. We can have a sense of ownership of the solutions and then see the difference (E04).

E04 perceived that Fintech RE could lower the barrier of entry for the Hong Kong public to participate in energy transactions and indirectly invest in renewable energy. E04 considered this an opportunity to open a previously thought unreachable vast potential market. E04 dubbed this innovation for integrating energy systems almost like a "social transformation" on how people would view energy and its application in their lives, saying:

> The social benefits would be essential because the beauty of Fintech is that it lowers entry barriers for everyone to participate in solar or energy transactions. You can say it is almost like a social transformation. In Hong Kong, we are traditional in terms of policies. We are quite used to relying on the government and power companies. We, Hong Kong people, do not feel too bad about that. Everything is like falling into the right place, and we do not have many problems. So, I think Fintech opens new opportunities. Now, if you do something and we do things together, maybe collectively on a community scale, we can make an impact (E04).

Fintech RE could also lead to new job creation. E11 said, "If the Fintech RE market is created, we can stimulate research and attract more people to join this new industry." The same respondent perceived that Fintech RE could develop new start-ups. E11 shared:

> If Hong Kong can incorporate Fintech into its power sector, Hong Kong could draw more attention to Fintech and, maybe, CLP and HK Electric will be more willing to invest in Fintech RE. CLP has a subsidiary called CLP Innovation, which is focused on this kind of technology. They should have already identified, if not created and generated, spaces for potential start-ups to develop these new products (E11).

4.2. Perceived challenges

4.2.1. Hong Kong's extant electricity market and reluctance by policymakers

One of the challenges for Fintech RE in Hong Kong is its relatively small market size. E08 shared that this market is too small for a Fintech RE ecosystem. Hong Kong's electricity sector is already reliable, secure, and affordable, which prompted E08 to ask: "if Fintech RE is all moving in the direction of safety, affordability and reliability, what is the technology or this innovation trying to solve?"

E08 noted that the crucial and significant institutional roadblock for Fintech RE in Hong Kong is the monopoly situation of its energy market. Contrasting it with Australia, an open market, E08 provided an example:

> The market system is very different in Hong Kong, unlike in Australia, for example, where energy is traded, and, every day, people are buying and selling. Suppose there are already transactional processes in Hong Kong, then, of course. In that case, Fintech can be applied to it to make energy trading more efficient, faster, transparent, and secure (E08).

E04 also raised the point that Hong Kong people are complacent in terms of the status quo of the current system in place. E04 used the statements: "Everything is like falling in the right place" and "we don't have many problems" to cite the city's efficient electricity system and the affordability of its electricity supply. If Fintech RE is to thrive, E01 pointed out that the Hong Kong government has a vital role by fully supporting this innovation. E01 said:

> You need the government to back this fully and say, okay, we are going to democratise, you know, we will make energy, a distributed system rather than be controlled by the two utilities. They need to be behind it and change some or set up policies to encourage it (E01).

On the assumption that Fintech RE will materialise in Hong Kong in the future, E04 raised a point about how market rules need to be worked out:

> Building up the finance system in Hong Kong is a complicated engineering effort because we have had enough bad experiences. We have green bonds and renewable energy certificate systems, but they are not at scale, at least for the latter. I won't underestimate the challenge of setting up and making something work, like an energy blockchain trading platform. The first thing is how we can work out nice sets of market rules so that we know how each carbon coin is valued and help everyone recognises that value. The challenge is getting people familiar with such new or innovative concepts. You know that bitcoin or companies like that can easily attract suspicion and scandals, so how can we prepare well for it? I am unsure whether the Hong Kong government is ready to play a competent role in nurturing or regulating these new financial markets (E04).

E02 also acknowledged the challenge related to the mentality of policymakers, saying:

> The main challenge is the mentality of the policymakers. They are very conservative, although they like innovation and talk about innovation. There is a whole office about innovation. But it looks at innovation in a very traditional way. It does not want to push for new things (E02).

4.2.2. Public understanding of Fintech RE and perceived low investment returns

E01 said there would be a lot of education needed for Fintech RE to be successful in Hong Kong, saying:

> There will be a lot of education that needs to be done. You do not need to educate the financier or the banks because money is to be made. They can package your deal to make it happen. Blockchain technology is already there. These tokenisation and securitisation are nothing new. We have done that for ages in the financial markets. We have the Sustainable & Green Exchange already. We need some sort of policy and education so that the entities that can do that will embrace it. In Hong Kong, there are so many big and small companies, and they are very resourceful. But those who can try this and can support this are only a handful. We need to demonstrate to them that there are long-term benefits to be made. Even though they may not recover all the costs in the short term, it is even worth tokenising the revenue units and selling them to investors (E01).

The financial profitability of Fintech RE investing, thus, is another crucial challenge. E08 opined that the economic profitability of Fintech RE investment is lower than the bonds investment. For example, there are different investment opportunities in venture capital and funds investment which have potential capital gains in the short term that Fintech RE could not offer.

While Fintech RE could be an excellent idea for new investment, it could not be that attractive because the returns on these investments are not that high. Fintech RE is not something one can make money day in and day out, which many investors in Hong Kong are doing. E08 expounded:

> The other piece was the opportunity to invest. It is a great idea, but the return is not that high because these investments do not pay. It is not something you can speculate on and make money from day in and day out (E08).

Continuing their evaluation of this future investment vehicle, E08 disagreed that Fintech RE could add significant investment value compared to, for example, investing in bonds. They said: "I don't think Fintech RE can add much value. It is more like the bonds we would benefit greatly from (E08)."

5. Discussion

5.1. Fintech RE opportunities and constraints for Hong Kong's green finance ambition and the investing public

Hong Kong could offer new investment opportunities while prodding innovation in sustainability via Fintech RE. While respondents regarded the energy transition and finance as distinct sectors, they still saw the possibilities for merging them via Fintech RE while being cautious about its effectiveness, especially given the constraints of the city's regulated electricity sector.

The small size of Hong Kong offers the city the opportunity to structure Fintech RE at this scale. For example, small-scale renewable energy generation and storage systems in housing estates could comprise solar rooftop PV arrays or building-integrated wind turbines, complemented with building battery storage. These arrangements could better serve the on-site energy demand of Hong Kong's housing estates by making them smarter with the Internet of Things connected to Fintech, where network members could perform energy trades.

In chorus, our respondents regarded this plausible digital financialisation of Hong Kong's energy sector as an avenue for investment, expanding present opportunities available in the market. In a way, this suggests the finance mindset of many of our respondents. Therefore, the public stands to win in the Fintech RE innovation since it allows diversifying their investment portfolios. As a caveat, however, investing in Fintech RE will have its risks, as with other types of investments, such as market, liquidity, inflation, and credit risks, among others.

Additionally, introducing Fintech RE in the city opens new opportunities for entrepreneurship, especially for start-ups across at least three sectors: energy, finance, and the digital economy. New jobs and roles will most likely spring up as new talents are required in this unique ecosystem. In this regard, Fintech RE also signifies the need for education and skilling, requiring universities to offer new courses and degrees to fill this new demand for new jobs and roles.

Fintech RE also allows the public to participate indirectly in climate action. As new capital is mobilised through these digital platforms, RE can be deployed at scale and speed. It must be noted, however, that this benefit is not yet demonstrated, even within extant examples. Common among the responses was that Fintech RE could allow electricity end-users to participate actively in the Hong Kong energy market, a specific characteristic of the technology.

However, all respondents also noted there would be almost zero opportunity for Fintech RE in Hong Kong unless the electricity market becomes liberalised and innovation in RE trading arrangements arises. Once the electricity market was liberalised, respondents were also in chorus, noting the need for new market rules to allow the technology to thrive. Acknowledging the crucial role of public understanding of energy transition and digital finance, our respondents remarked on the need for educating investment houses and the public on this innovation.

5.2. Towards a regional scale Fintech RE ecosystem for the Greater Bay Area

Yet, another Fintech RE opportunity was not explored in this paper: a regional peer-to-peer digital energy trade protocol for the Guangdong-Hong Kong-Macao Greater Bay Area (GBA). The GBA comprises the two special administrative regions of Hong Kong and Macao and the municipalities of Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen, and Zhaoqing in Guangdong Province. Hong Kong's city-scale Fintech RE could be scaled in the GBA by interconnecting this market with Macao's and others. With the Hong

Kong Climate Action Plan 2050 hinged on strengthening regional cooperation for renewable energy import-export within the GBA, a GBA-wide Fintech RE could open new opportunities for accelerating a regional energy transition.

A regional-scale Fintech RE ecosystem also signifies a much bigger opportunity for start-ups, new jobs, and large-scale decarbonisation impacts; however, China's current prohibition of PoW blockchain constrains this prospect.

5.3. Accounting for Fintech RE's decarbonisation issues

It is also interesting to note one missing item in the interview data: the potential of Fintech RE to derail, decelerate, and slack the decarbonisation process given the need for more energy in performing trade verifications, which, if sourced from carbon-based fuels, could only lead to more emissions. While Fintech RE offers a vehicle for direct participation by electricity consumers in energy transition and the city's decarbonisation efforts, one could not simply ignore the climate cost due to this emergent technology. The reasons why this crucial impact is captured in the interviews are, at this point, unknown, hence, meriting future research.

The carbon pollution impact of Fintech on an international finance centre, such as Hong Kong, is an essential avenue for designing future climate and energy policy. Ensuring that Fintech RE is aligned with energy justice is another crucial aspect of this innovation. This means the costs and benefits of any decarbonisation activities – Fintech RE in this case – should be shared fairly and equally across [55,56,57]. While Fintech RE may thrive in Hong Kong in the future, emissions arising from crypto work in verifying RE trades could result in a zero-sum game, thus, invalidating its promised decarbonisation benefits.

6. Conclusion

In closing, Fintech RE could assist in decarbonising Hong Kong's energy systems since it supports the expansion of distributed RE generation in ways more appealing to financially savvy electricity consumers. Fintech RE promises to democratise energy generation and distribution while making an economic case for it. However, whether this innovation will be taken up at scale could never be guaranteed. If the city's existing feed-in tariff scheme is an indicator, Fintech RE might not also be that attractive. However, Fintech RE might be positively taken given the city's position as a centre of international finance.

The attendant blockchain platforms Fintech RE entails also mean the emergence of start-ups and the creation of new jobs unavailable in the feed-in tariff ecosystem. The investing public would be provided with a unique opportunity to participate in energy trading in their neighbourhoods while simultaneously becoming direct participants in low-carbon development. These may give new impetus to support the deployment of this innovation in Hong Kong.

If Fintech RE becomes a reality in Hong Kong, extant institutional arrangements where Schemes of Control regulate the city's electricity sector need a rethought. The monopolies held by CLP and Hong Kong Electric stand to be challenged since, virtually and essentially, the industry must open up to multiple renewable energy generators that they need to accommodate. This situation warrants new energy governance and institutional arrangements, which become messier and more complex as Fintech becomes involved. Since Fintech and small-scale on-site renewable energy generation and storage systems require heavy decentralisation with little room for centralised regulation (which is the essence of the existing Schemes of Control), this future arrangement necessitates new market rules and governance approaches.

It is also crucial to mention the central government's prohibition of PoW authentication methods in validating blockchain transactions, a Beijing-instituted policy that could cascade in Hong Kong. With this type of verification currently under intense criticism for its high energy consumption and emissions, Fintech RE would remain a contentious tool for decarbonisation, derailing opportunities to achieve the SDGs, especially on energy transition (SDG7) and climate action (SDG13). Efficient and low-carbon crypto mining work should be considered the solely supported mechanism for Fintech RE in Hong Kong. If not, ensuring that the energy supplied for verification work would be strictly from 100 % renewable energy sources would be crucial. Unless these conditions are met, Fintech RE will remain a contentious vision as an innovative tool for meeting the triangle of decarbonisation, digitalisation, and decentralisation of the city's energy system.

Declaration of competing interest

We declare no conflict of interest.

Data availability

The data that has been used is confidential.

Acknowledgements

The Hong Kong University of Science and Technology Undergraduate Research Opportunities Program Support Grant supported this work. I thank Rainbow Hi Yung Lam, Wing Shun Vincent Tang, and Ka Ying Christy Wong for their assistance in data collection and data cleaning. I also thank two anonymous reviewers for their helpful comments.

References

[1] Stacks, A conversation with Naval Ravikant and Ryan Shea, Blockstack Summit 2017. youtube.com/watch?v=IrSn3zx2GbM, 2017.
[2] Hong Kong Special Administrative Region, Government announces Hong Kong's climate action plan 2050Press Releases. https://www.info.gov.hk/gia/general/202110/08/P2021100800588.htm, 2021.
[3] Hong Kong Special Administrative Region, Hong Kong's climate action plan 2050. https://www.climateready.gov.hk/files/pdf/CAP2050_booklet_en.pdf, 2021.
[4] Hong Kong Monetary Authority, Hong Kong as an international financial centre. https://www.hkma.gov.hk/eng/key-functions/international-financial-centre/hong-kong-as-an-international-financial-centre/, 2021.
[5] Y. Luo, The current situation and opportunities for the development of green finance in Hong Kong: taking green bonds as an example, J. Econ. Financ. Account. Stud. 4 (3) (2022) 70–74.
[6] K. Branker, E. Shackles, J.M. Pearce, Peer-to-peer financing mechanisms to accelerate renewable energy deployment, J. Sustain. Financ. Invest. 1 (2) (2011) 138–155.
[7] C.P.S. de Brauwer, J.J. Cohen, Analysing the potential of citizen-financed community renewable energy to drive Europe's low-carbon energy transition, Renew. Sust. Energ. Rev. 133 (2020), 110300.
[8] M.L. Di Silvestre, S. Favuzza, E.R. Sanseverino, G. Zizzo, How decarbonization, digitalization and decentralization are changing key power infrastructures, Renew. Sust. Energ. Rev. 93 (2018) 483–498.
[9] S. Knuth, "Breakthroughs" for a green economy? Financialisation and clean energy transition, Energy Res. Soc. Sci. 41 (2018) 220–229.
[10] A.D. Valdivia, M.P. Balcell, Connecting the grids: a review of blockchain governance in distributed energy transitions, Energy Res. Soc. Sci. 84 (2022), 102383.
[11] R. Tao, C.W. Su, B. Naqvi, S.K.A. Rizvi, Can fintech development pave the way for a transition towards low-carbon economy: a global perspective, Technol. Forecast. Soc. Chang. 174 (2022), 121278.
[12] C.L. Gunarathna, R.J. Yang, S. Jayasuriya, K. Wang, Reviewing global peer-to-peer distributed renewable energy trading projects, Energy Res. Soc. Sci. 89 (2022), 102655.
[13] J. Hwang, M. Choi, T. Lee, S. Jeon, S. Kim, S. Park, S. Park, Energy prosumer business model using blockchain system to ensure transparency and safety, Energy Procedia 141 (2017) 194–198.
[14] L.L. Delina, J. Ocon, E. Esparcia Jr., What makes energy systems in climate-vulnerable islands resilient? Insights from the Philippines and Thailand, Energy Res. Soc. Sci. 69 (2020), 101703.
[15] D. Krantz, Solving problems like Maria: a case study and review of collaborative hurricane-resilient solar energy and Autogestión in Puerto Rico, J. Sustain. Res. 3 (1) (2020).
[16] D. Brown, S. Hall, M.E. Davis, What is prosumerism for? Exploring the normative dimensions of decentralised energy transitions, Energy Res. Soc. Sci. 66 (2020), 101475.
[17] R. Zafar, A. Mahmood, S. Razzaq, W. Ali, U. Naeem, K. Shehzad, Prosumer based energy management and sharing in smart grid, Renew. Sust. Energ. Rev. 82 (2018) 1675–1684.

[18] C. Nolden, J. Barnes, J. Nicholls, Community energy business model evolution: a review of solar photovoltaic developments in England, Renew. Sust. Energ. Rev. 122 (2020), 109722.
[19] A. Gill-Wiehl, S. Miles, J. Wu, D.M. Kammen, Beyond customer acquisition: a comprehensive review of community participation in mini grid projects, Renew. Sust. Energ. Rev. 153 (2022), 111778.
[20] A. Pena-Bello, D. Parra, M. Herberz, V. Tiefenbeck, M.K. Patel, U.J. Hahnel, Integration of prosumer peer-to-peer trading decisions into energy community modelling, Nat. Energy 7 (1) (2022) 74–82.
[21] E.A. Soto, L.B. Bosman, E. Wollega, W.D. Leon-Salas, Peer-to-peer energy trading: a review of the literature, Appl. Energy 283 (2021), 116268.
[22] M. Mehdinejad, H. Shayanfar, B. Mohammadi-Ivatloo, Peer-to-peer decentralised energy trading framework for retailers and prosumers, Appl. Energy 308 (2022), 118310.
[23] C. Lamnatou, D. Chemisana, C. Cristofari, Smart grids and smart technologies in relation to photovoltaics, storage systems, buildings and the environment, Renew. Energy 185 (2021) 1376–1391.
[24] H.M. Butu, B.E.K. Nsafon, S.W. Park, J.S. Huh, Leveraging community based organisations and Fintech to improve small-scale renewable energy financing in Sub-Saharan Africa, Energy Res. Soc. Sci. 73 (2021), 101949.
[25] M. Andoni, V. Robu, D. Flynn, S. Abram, D. Geach, D. Jenkins, A. Peacock, Blockchain technology in the energy sector: a systematic review of challenges and opportunities, Renew. Sust. Energ. Rev. 100 (2019) 143–174, https://doi.org/10.1016/j.rser.2018.10.014.
[26] E. Mengelkamp, J. Gärttner, K. Rock, S. Kessler, L. Orsini, C. Weinhardt, Designing microgrid energy markets: a case study: the Brooklyn microgrid, Appl. Energy 210 (2018) 870–880.
[27] Y. Lu, The blockchain: state-of-the-art and research challenges, J. Ind. Inf. Integr. 15 (2019) 80–90.
[28] Z. Dong, F. Luo, G. Liang, Blockchain: a secure, decentralised, trusted cyber infrastructure solution for future energy systems, J. Modern Power Syst. Clean Energy 6 (5) (2018) 958–967.
[29] P.W. Khan, Y.-C. Byun, Blockchain-based peer-to-peer energy trading and charging payment system for electric vehicles, Sustainability 13 (14) (2021) 7962.
[30] S. Baidya, V. Potdar, P.P. Ray, C. Nandi, Reviewing the opportunities, challenges, and future directions for the digitalisation of energy, Energy Res. Soc. Sci. 81 (2021), 102243.
[31] S.-K. Kim, J.-H. Huh, Blockchain of carbon trading for UN sustainable development goals, Sustainability 12 (2020) 4021.
[32] F. Zhao, X. Guo, W.K. Chan, Individual green certificates on blockchain: a simulation approach, Sustainability 12 (2020) 3942.
[33] Brooklyn Microgrid, Brooklyn Microgrid webpage. https://www.brooklyn.energy/, 2019.
[34] M.E. Peck, D. Wagman, Energy trading for fun and profit buy your neighbor's rooftop solar power or sell your own-it'll all be on a blockchain, IEEE Spectr. 54 (10) (2017) 56–61.
[35] C. Mora, R.L. Rollins, K. Taladay, M.B. Kantar, M.K. Chock, M. Shimada, E. C. Franklin, Bitcoin emissions alone could push global warming above 2 C, Nat. Clim. Chang. 8 (11) (2018) 931–933.
[36] J. Truby, Decarbonizing bitcoin: law and policy choices for reducing the energy consumption of blockchain technologies and digital currencies, Energy Res. Soc. Sci. 44 (2018) 399–410.
[37] J. Truby, R.D. Brown, A. Dahdal, I. Ibrahim, Blockchain, climate damage, and death: policy interventions to reduce the carbon emissions, mortality, and net-zero implications of non-fungible tokens and bitcoin, Energy Res. Soc. Sci. 88 (2022), 102499.
[38] A. de Vries, U. Gallersdörfer, L. Klaaßen, C. Stoll, The true costs of digital currencies: exploring impact beyond energy use, One Earth 4 (6) (2021) 786–789; C. Schinckus, Proof-of-work based blockchain technology and anthropocene: an undermined situation? Renew. Sust. Energ. Rev. 152 (2021), 111682.
[39] S. Jiang, Y. Li, Q. Lu, Y. Hong, D. Guan, Y. Xiong, S. Wang, Policy assessments for the carbon emission flows and sustainability of bitcoin blockchain operation in China, Nat. Commun. 12 (1) (2021) 1–10.
[40] Reuters, China bans financial, payment institutions from cryptocurrency business, 18 May. https://www.reuters.com/technology/chinese-financial-payment-bodies-barred-cryptocurrency-business-2021-05-18/, 2021.
[41] The New York State Senate, Senate bill S6486D establishes a moratorium on cryptocurrency mining operations that use proof-of-work authentication methods to validate blockchain transactions. https://www.nysenate.gov/legislation/bills/2021/S6486, 2021.
[42] P. Howson, Bitcoin: Why China's crackdown isn't enough. Independent, 7 June, https://www.independent.co.uk/voices/bitcoin-china-crackdown-energy-environment-b1861123.html, 2021.
[43] R. Browne, China's share of global bitcoin mining plunges while Kazakhstan climbs to third place. CNBC, 15 July, https://www.cnbc.com/2021/07/15/china-share-of-bitcoin-mining-falls-while-kazakhstan-surges.html, 2021.
[44] S. Vahia, Iran is bringing back cryptocurrency mining, but China shows no signs of changing its mind. Business Insider India, 25 August. https://www.businessinsider.in/cryptocurrency/news/cryptocurrency-mining-in-iran-easing-but-china-maintain-strict-stance/articleshow/85588848.cms, 2021.
[45] Hong Kong Monetary Authority, Joint Statement on the Establishment of the Green and Sustainable Finance Cross-agency Steering Group, HKMA, 2020, 5 May.
[46] C.L.P. Holdings, Feed-in tariff rates adjustment. https://www.clp.com.hk/en/feed-in-tariff-rate-adjustment, 2022.
[47] Hong Kong Electric, Feed-in tariff scheme. https://www.hkelectric.com/en/smart-power-services/feed-in-tariff-scheme, 2022.
[48] H. Ritchie, M. Roser, P. Rosado, Energy, OurWorldInData.org, 2020. https://ourworldindata.org/energy.
[49] D.N.Y. Mah, D.M.W. Cheung, M.K. Leung, M.Y. Wang, M.W.M. Wong, K. Lo, A. T. Cheung, Policy mixes and the policy learning process of energy transitions: insights from the feed-in tariff policy and urban community solar in Hong Kong, Energy Policy 157 (2021), 112214.
[50] P. Dato, T. Durmaz, A. Pommeret, Feed-in tariff policy in Hong Kong: is it efficient? City Environ. Interact. 10 (2021), 100056.
[51] M.S. Wong, R. Zhu, Z. Liu, L. Lu, J. Peng, Z. Tang, W.K. Chan, Estimation of Hong Kong's solar energy potential using GIS and remote sensing technologies, Renew. Energy 99 (2016) 325–335.
[52] L.L. Delina, Wind energy in the city: Hong Kong's offshore wind energy generation potential, deployment plans, and ecological pitfalls, Electr. J. 35 (6) (2022), 107139.
[53] B.G. Glaser, A.L. Strauss, The Discovery of Grounded Theory, Strategies for Qualitative Research. Routledge, 2017.
[54] G. Guest, E. Namey, M. Chen, A simple method to assess and report thematic saturation in qualitative research, PLoS One 15 (5) (2020), e0232076.
[55] K. Jenkins, D. McCauley, R. Heffron, H. Stephan, R. Rehner, Energy justice: a conceptual review, Energy Res. Soc. Sci. 11 (2016) 174–182.
[56] B.K. Sovacool, M.H. Dworkin, Energy justice: conceptual insights and practical applications, Appl. Energy 142 (2015) 435–444.
[57] L.L. Delina, B.K. Sovacool, Of temporality and plurality: an epistemic and governance agenda for accelerating just transitions for energy access and sustainable development, Curr. Opin. Environ. Sustain. 34 (2018) 1–6.