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Incorporating seller/buyer reputation-based system in blockchain-enabled emission trading application

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HIGHLIGHTS

- A blockchain-enabled system is proposed for emissions trading application.
- The objective is to improve management and increase abatement investment.
- Financial incentive is used to motivate industry participants.
- Multi-criteria analysis emphasizes the benefit of the system against established ETS.

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ABSTRACT

Emission Trading Scheme (ETS) has dual aims to reduce emission production and stimulate adoption of long-term abatement technology. Whilst it has generally achieved its first aim, its issues are hindering the accomplishment of the second. Several solutions have been proposed to improve ETS's efficacy, yet none of them have considered the advancement of Industry 4.0. This paper proposes a novel ETS model customised for Industry 4.0 integration. It incorporates blockchain technology to address ETS's management and fraud issues whilst it utilizes a reputation system in a new approach to improve ETS efficacy. Specific design of how the blockchain technology and reputation system are used to achieve these objectives is showed within this paper. The case study demonstrates the inner working of reputation-based trading system—in which reputation signifies participants performance and commitment toward emission reduction effort. Multi-criteria analysis is used to evaluate the proposed scheme against conventional ETS model. The result shows that the proposed model is a feasible scheme and that the benefits of its implementation will outweigh its drawback.

1. Introduction

Energy consumption is the main contributor to global emission. About 76% of world emissions in 2010 arose from the need to generate energy, mainly for electricity and industrial processes [1]. From 2015 to 2040, an increase of 16% is predicted for energy-related CO_2 emissions worldwide [2]. Carbon dioxide made for 75% of the global greenhouse gas emission in 2010 and will continue to rise at an average of 0.6% per year between 2015 and 2040—most of it stems from fossil fuel combustion [1,2]. Considering the effect of greenhouse gas emissions to climate change [3], various studies have been conducted and several solutions have been proposed; including converting CO_2 to valuable products, adjusting operational procedure to lower CO_2 production, and capturing the CO_2 for storage. However, there are little initiatives in the implementation of these solutions, most of the time due to the financial burden that these solutions incur.

Imposing a price to emission products is believed to be an effective method to lower the reluctance in reducing emission production. One option to do that is through Emission trading scheme (ETS) or cap-and-trade scheme. In 2016, 17 ETSs were active worldwide and more governmental bodies were considering its implementation [4]. Each of them differs in their specific regulations. Whilst this policy measure has been able to reduce emission production, it still has several problems that undermine its effectiveness [5,6]. Furthermore, it is yet to make significant progress in encouraging investment in technologies that provide long term abatement effects [7,8]. Therefore, a complementary measure is needed to increase the policy effectiveness, encourage adoption of these technologies and thereby support a long term solution [9].

Previous studies has proposed and studied several options in

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improving the efficiency of Emission Trading Scheme (ETS). Perino and Willner [10] discusses the EU-ETS options to postpone the introduction of new permits when there is a surplus in the market in order to bolster the price of the permits. The proposal to create a central authority that adjust the supply of permits to stabilize the price of the permits is presented in [11]. The possibility of introducing a carbon floor price to guarantee a minimum price of permits is explored in [12]. A different allowance allocation methods that involves the adjustment of the pre-allocation based on the enterprises' actual output and carbon intensity is applied in Shenzen's ETS—the first regional level of ETS in China—to avoid oversupply of permits and windfall profits [13–15]. All previous proposals share a similarity in their objective to control the price of the permit by decreasing the supply or introducing a minimum price; the ultimate purpose being to increase the global price of the permits to a certain level, so that purchasing more permits becomes the less attractive option. However, these solutions will not be able to fully accomplish their objective while the integrity of the entire policy is still an issue. Furthermore, none of these proposals customise their solution to suit the change Industry 4.0 may cause to the way the industries will operate in the future.

The fourth industrial revolution, Industry 4.0 is characterized by high degree of process automation and digitisation that will increase flexibility and efficiency for manufacturing and service industries [16–20]. Integrating the concept of Industry 4.0 with established systems leads to the realization of a smart system. Amongst them is integration with Eco-Industrial Park (EIP) to realise a smart EIP. As part of J-Park Simulator (JPS) project that intends to showcase a realised smart EIP [21–24], we try to customise a novel ETS model that is thoroughly supported by the smart EIP's intelligent and automated systems and devices, and is able to take a full advantage of that support. Furthermore, the model is expected to construct a different approach in solving ETS issues by leveraging that support.

The paper propose a novel ETS model that is supported by the digitisation and automation of Industry 4.0 that has also provided the foundations for machine-to-machine (M2M) transaction. For such transaction, reliable and secure system is a vital requirement to manage the complexity of the new paradigms [20]. Blockchain technology is chosen as the tools to accomplish that and utilized to solve ETS's inefficient management and fraud issues. On the other hand, the use of blockchain technology also made it possible to apply a different approach to discourage participant from purchasing more permits. Instead of introducing a price control measure, it introduces a new approach to encourage the adoption of more sustainable and long-term solutions. Previous study [25] have found reputation system to be an effective method to secure participants' good behaviour and to improve market quality. Integration of reputation system to trading mechanism—in which the reputation indicates participant performance and commitment to emission reduction effort—is used to achieve this aim. However, reputation-based trading system cannot be easily realised in a current ETS environment. The issue will be the integrity of each reputation-based transaction being executed. But, with the support of blockchain technology, transactional integrity can be preserved by applying a specific trading algorithm as part of the blockchain transaction procedure.

Thus, the first objective is to show the use of blockchain technology to solve ETS's management and fraud issues whilst the second objective is to show the use of reputation system to encourage investment in long-term abatement technology. The system showed in this paper is applied to a basic ETS policy that accepts carbon credits generated through the Clean Development (CDM) and Joint Implementation (JI) programmes. The customisation's focus is the trading mechanism and the monitoring and reporting procedure, therefore, the system is expected to be able to accommodate any modification in permits issuance and distribution method as well as other separate areas.

The paper is organized as follows: Section 2 provides the background on emissions trading schemes and blockchain technology. Section 3 presents the methodology in designing the new ETS model. Section 4 shows a case study that exhibits the inner workings of the reputation-based trading system and the applications. Section 5 shows the evaluation of the proposed scheme against a conventional emission trading scheme using a multi-criteria analysis. Finally, Section 6 provides the conclusion and future work plan regarding the application.

2. Background

2.1. Emission trading

Two recognized methods to levy a price for producing emissions are carbon taxes and tradable permits [26,27]. The difference between the two lies in the price generation method: in taxes case, the price is fixed and determined by policy makers; in tradable permits case, the price is the result of supply and demand. Both policy options have been analysed and compared many times in different aspects and situations with mixed results; some researchers find both equally effective, whilst other favours one over the other [27–31].

The tradable permits policy is also known as ETS or cap-and-trade scheme. It sets a limit or a cap to the type and amount of GHG that the sectors under its jurisdiction are allowed to produce. Equal number of permits that allows participants to emit GHG are then created and distributed at the start of the period, either through free allocation or auction. At the end of the period, all participants are required to surrender the relevant amount of permits along with a report on the amount of emission produced during that period.

Permits are tradable between participants. Entities with excess permits may sell them to others who have produced more emissions than they have permits for. Depending on the policy, in the event an entity cannot source enough allowance to comply with the regulation, sanctioned offset may be used to counterbalance the excess [26]. This offset is emission reduction that is done in a different location, with the aim of achieving carbon neutrality. Carbon neutrality means the amount of emission produced, in carbon dioxide equivalent (CO_2e) unit, is the same as the amount of emission reduced or sequestered.

The advantage of emissions trading is that there is a clear emission reduction target to be achieved. In addition, the scheme is also cost efficient. This is due to the fact that the cost of reducing emission may well vary between firms and this method provides flexibility for the participant to meet their obligation using the most cost efficient method [32,33]. The scheme also provides an opportunity for a concerned party to tighten the limit by buying and surrendering the allowances [32]. Another point in favour of tradable permits policies relates to the global emission abatement effort. With this scheme, it is possible to link the individual systems in order to create a larger and more stable market and to motivate developing countries' involvement [26,34].

There are several key elements to be considered in designing an ETS policy [26]. Those elements are:

- Scope, it includes the decision of economic and industrial sectors and the type of gases to be covered.
- Cap allocation, it determine emission reduction goals and the limit of emissions—and therefore the amount of permits—to be issued. It also includes period to specify the length of time the limit and the permits stay relevant. Flexibility refers to the options to keep unused permit relevant in the following periods. It is included under cap allocation due to its effect on the future cap if permits issued in a period stay relevant after the end of that period.
- Allowances or permits distribution. Permits can be distributed through free allocation, auction, or the combination of the two.
- Offset policy. It specifies whether an offset can be used in the scheme, what type of offset is allowed, its acceptable source and the limit of the amount.
- Trading mechanism specifies the rules of emission trading.
- Monitoring, Reporting and Verification (MRV) procedure. It defines