ISSN 2392-1641
e-ISSN 2450-0097

Economics and Business Review

Volume 8 (22) Number 3 2022

CONTENTS

Poznań University of Economics and Business Press

Paper based publication

ISSN 2392-1641
e-ISSN 2450-0097

POZNAŃ UNIVERSITY OF ECONOMICS AND BUSINESS PRESS
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www.wydawnictwo.ue.poznan.pl, e-mail: wydawnictwo@ue.poznan.pl
postal address: al. Niepodległości 10, 61-875 Poznań, Poland

Printed and bound in Poland by:
Poznań University of Economics and Business Print Shop

Circulation: 200 copies

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Economics and Business Review

Volume 8 (22) Number 3 2022

CONTENTS

Economics and Business Review, Vol. 8 (22), No. 3, 2022: 109-125
DOI: 10.18559/ebr.2022.3.6

Energy tokens as digital instruments of financial investment[1]

Kamilla Marchewka-Bartkowiak[2], *Marcin Wiśniewski*[3]

Abstract: The aim of the paper is to evaluate the investment attractiveness of selected energy tokens from the point of view of the effectiveness measures applied to ordinary financial instruments. The authors also classify energy tokens among climate-aligned tokens and digital instruments of green investments financing. In this way, it was possible to compare energy tokens against traditional financial instruments. Furthermore, the authors attempted to investigate the relationship between the formation of returns of the researched energy tokens and the returns on stock and commodity markets. The results of the study indicate the low investment attractiveness of energy tokens compared to investments in stock markets, commodity markets and investments in major cryptocurrencies such as Bitcoin and Ethereum. The research therefore indicates that buyers of energy tokens today should not be driven by investment or speculative motives but rather by a desire to obtain a means of clearing energy trading, or other utility.

Keywords: digital tokens, tokenization, climate-aligned tokens, energy tokens, investment efficiency.

JEL codes: G11, G12, O13, Q54.

Introduction

The ever advancing climate change requires the taking of immediate action if we want to halt environmental degradation and ensure the energy security. This issue has become so important and pressing that in 2015 the UN passed the Resolution on Sustainable Development Goals, among which climate and energy issues were

[1] Article received 19 May 2022, accepted 16 September 2022. Acknowledgment: The project financed within the Regional Initiative for Excellence programme of the Minister of Education and Science of Poland, years 2019–2023, grant no. 004/RID/2018/19, financing 3,000,000 PLN.
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prioritised (United Nations, 2015). The latest report of the Intergovernmental Panel on Climate Change leaves no illusions that climate change can be stopped now. The authors predict that over the next twenty years, global temperatures will on average reach or exceed a 1.5°C increase (IPCC, 2021). Hence the numerous calls for governments and international associations (such as the European Union) to accelerate action regarding the climate and energy policy.

On 7 March 2018 the European Commission launched the Action Plan for Financing Sustainable Growth aimed at encouraging and promoting sustainable investment. This act is in line with the European policy for a new sustainable world and continues the work carried out by European authorities following the Paris Agreement and the UN Agenda (EC, 2018). It is therefore becoming a priority for the EU to implement the Green Deal strategy and in particular the energy sector which is responsible for 75% of the EU's greenhouse gas emissions (EC, 2019). It should also be noted that the European Union is increasingly promoting further legislative initiatives related to financing and investing in sustainable and green assets (investments) such as the Sustainable Finance Disclosure Regulation (European Parliament and the Council, 2019), among others, which is a set of new regulations that help to better classify the sustainable specification of investment funds and the new EU Taxonomy, which offers a classification for economic activities that are green and sustainable.

The energy market is therefore becoming an increasingly attractive market from the point of view of financing and investment including digital investment (Andoni et al., 2019). Furthermore the use of the decentralised ledger technology (DLT) and the tokenization process is increasingly being considered in the energy sector. According to the Union of the Electricity Industry, which represents 3,500 energy sector companies across Europe, a blockchain enables secure data storage and executing smart contracts in peer-to-peer networks. Owing to its unique attributes, this technology has the potential to play a significant role in the energy sector. The possible solutions that could be implemented across the electricity supply chain, with regard to process optimization, include networks and trading platforms as the traditional wholesale trading as well as peer-to-peer (Eurelectric, 2017).

The main aim of the article is to answer the question about the attractiveness of energy tokens as an instrument for financial investment and diversification of the investment portfolio of market investors. To realize this objective the authors will also identify energy tokens among financial green instruments and climate-aligned tokens based on their use to date.

To the best of the authors' knowledge this is the first analysis ever to include energy tokens in a portfolio analysis as financial instruments. This is because so far the main focus has been on researching this digital token in its payment and utility function only.

The article is organised into three main sections. The first section presents an analysis of the research and literature on the new blockchain technology and climate-aligned tokens in the energy sector. In the next section the authors describe the essence and classification criteria of energy tokens and present data and the research methodology. In the last section the results of empirical studies conducted on the investment efficiency of energy tokens are presented and their portfolio attractiveness.

1. Literature review

The last decade has seen a sharp increase in the volume and value of green assets issued by the public and private sectors (Wiśniewski & Zieliński, 2019, pp. 83–96). According to the Climate Bond Initiative (BI, 2022), in 2021 the global green bond market was worth USD 1.6 tn—dominated by bonds issued by sovereigns, government-back entities, local governments and development banks. Additionally, sustainability bonds, which finance the implementation of both green and social goals, appeared in the statistics. In 2021 the value of the market for these bonds amounted to USD 520.5 bn, and their issuers included mainly development banks, however not excluding sovereigns, government-backed entities and local governments. This path is also being followed by private entities which increasingly use repayable financing (loans, bonds) of green nature. The commitments entered into finance green activities specified by the issuer, which constitutes an incentive for social and environmental responsible investors to purchase these instruments. In order for an investor to be confident in the greenness of their investment certification by institutions such as the Climate Bond Initiative, CICERO, Moody's Green Bond Assessments and Standard & Poor's Green Evaluation is required (Ehlers & Packer, 2017, p. 93). It is emphasised that such certification makes it easier for a green debt issuer (both public and private issuer) to place a bond issue and reduces the investor's margin, thus reducing the cost of debt, due to the additional bonus investors receive in the form of the belief that they are doing something valuable for the environment (Wiśniewski & Zieliński, 2019, pp. 83–96).

Modern technologies and digital tokens based on them are increasingly becoming an alternative to the so-called traditional methods of financing climate and energy policy. Nowadays many different applications of the DLT technology can be found as far as energy is concerned. First of all blockchain is used in energy trading—buying and selling individually generated energy—by individual users. With the help of this technology electricity trading platforms are created, services enabling payment for charging electric vehicles at stations, or giving users the opportunity to quickly change energy service providers (Basden & Cottrell, 2017). The literature highlights that the use of new technological solutions can increase the security of energy trading as the technology perfectly allows for confirmation of ownership, it is a reliable and inexpensive way to conduct and control transactions without a central generation unit of power and promotes the development of the renewable energy microgrid. Moreover it introduces intelligent solutions and energy management systems to ensure universal and safe access to energy. Blockchain, through the liquidation of intermediaries and introduction of P2P transactions, also allows the reduction of energy prices under conditions of high competition (Varnavskiy et al., 2018, pp. 46–49). Researchers dealing with the possible applications of the technology described also point to its use for: crowdfunding of assets and distribution of revenue, facilitating green energy investments and assets co-ownership, bringing together sustainable energy projects and prospective investors, rewarding low-carbon and green energy production (Andoni et al., 2019, pp. 158–159).

Issuers of energy tokens are entities involved in providing clean energy, mediating its settlement, as well as implementing new solutions in the renewable energy market. Generally digital tokens or cryptoassets are defined as a digital representation of value or rights which may be transferred and stored electronically using the distributed ledger technology or a similar technology (EC, 2020). Digital tokens are currently used in many business models (Diedrich, 2016; Adhami, Giudici, & Martinazzi, 2018; Tönnissen, Beinke, & Teuteberg, 2020). Their diversity in terms of functionality has also given rise to the recognition of a new area of analysis called the Token Economy or Tokenomics for short (Mougayar, 2017). The most important division of digital tokens is mainly based on three aspects: the purpose of their creation, the function they are supposed to perform and their technical aspects.

Climate-aligned tokens can be used in a wide variety of ways for direct financing of climate and energy policy (on digital platforms); they can also be used as an investment instrument (e.g. for trading on digital stock exchanges) for clearing purposes (e.g. in energy trading) or for utility purposes, entitling their holder to certain services. It is also worth noting that although digital tokens are most often issued by institutional entities, personal tokens are becoming increasingly popular (Marchewka-Bartkowiak & Nowak, 2020). In future it should therefore be possible to use tokens by households or individuals in the climate-energy area not only as beneficiaries, but also as issuers of tokens (e.g. of energy surpluses). From a technical point of view, the construction of climate-aligned tokens can be based on existing functionalities of digital tokens such as technological link with platforms, a price stability standard or smart contract.

Energy tokens can thus be considered as a means of payment in a clearing or utility function (Varnavskiy et al., 2018; Andoni et al., 2019) but also as a commodity (Guseva, 2021, pp. 175–176) or decentralised means of investments (Lin & Tjio, 2020, p. 1). Thus these tokens can also represent an alternative form of investment compared to classical financial instruments such as stocks, bonds or mutual fund units. Even if they are not "equity" tokens, which are a digitalised form of financial instruments, they can be regarded as an alternative investment such as investments in commodities (oil, metals, grain).

2. Data and research methodology

Referring to the above considerations the authors decided to propose two classification of energy tokens as the basis for the research. The first looks at the a role of energy tokens as a green instrument issued to finance tasks and activities of climate and energy policy (Table 1). In this classification energy tokens are considered as the modern (digital) and private issued financial instrument based on the digital technology (DLT).

Table 1. Financial instruments in financing tasks and activities regarding climate change

Economy sector	Financial instruments	
	Traditional	Modern (digital)
Public	**Budgetary sources** (including budgetary spending on green investments, green tax credits, public taxes and charges on entities acting to the detriment of the environment, public revenues from green debt, especially green bonds)	**Climate-aligned tokens** (e.g. green bond tokens)
Private	**ESG-linked loans and securities** (including green bonds and loans)	**Climate-aligned tokens** (e.g. energy, climate, green tokens)

Source: Own elaboration.

The second classification takes into account three of the above mentioned general functionalities such as: technological links with digital platforms, price stability standard and a digital contract. The characteristics of climate-aligned tokens within the framework of digital tokens classification accepted in the literature (BIS, 2018; FSB, 2018; ESMA, 2018; ECB, 2019; OECD, 2019; FCA, 2018; Oliveira, Zavolokina, Bauer, & Schwabe, 2018) are presented in Table 2.

Table 2. Energy tokens features

Criteria	Energy tokens features
Aim of the creation (issuance)	Climate-aligned tokens
The value or rights represented	Exchange type (payment tokens) Utility type (utility tokens) Investment type (asset or security tokens)
Type of the issuance	Private sector Institutional or individual entities
Method of technological link	Native or non-native tokens
Price/value stability standard	Stable or non-stable tokens
Digital contract	Fungible or non-fungible tokens

Source: Own elaboration.

Table 3. The energy tokens under study

Acronym	Name	Market capitalisation (USD)*	Date of "issuance"	Characteristics
POWR	Power Ledger	197 428 960	08/11/2017	native token which uses public ETH blockchain designed to enable local areas to sell and distribute solar power without the help of middlemen and used to facilitate energy and environmental commodity trading
EWT	Energy Web Tokens	177 804 438	31/03/2020	native token behind the Energy Web Chain, a blockchain-based virtual machine designed to support and further application development for the energy sector; used to create DApps
WOZX	EFFORCE	59 458 114	07/12/2020	native cryptocurrency token of energy efficiency platform Efforce used as the medium through which energy savings created on the Efforce platform are tokenized for use by any participant
GRID+	GRIDplus	44 625 760	02/03/2018	cryptocurrency operating on the ETH platform, that gives consumers direct access to wholesale energy markets (USA)
CHG	Charg Coin	7 602 264	14/06/2018	native coin which binds energy to money using the power of electric vehicle charging as a basis of value; time of charging vehicle (in Charge Coin network) is transformed into the price of the coin
SNC	SunContract	2 837 478	19/11//2017	native cryptocurrency which empower individuals to freely buy, sell or trade electricity by providing an open energy marketplace (Slovenia)
WPR	WePower	1 193 302	11/02/2018	a platform which allows green energy producers to raise capital by issuing these tokens
ELEC	Electrify.Asia	533 006	21/03/2018	cryptocurrency operating on the ETH platform that allows the trading of energy among individual producers of energy (Singapore)
TSL	Energo / Tesla	136 036	28/12/2017	native cryptocurrency which supports peer to peer power trading system by applying a blockchain to the microgrid for decentralized energy autonomy

* Data as of 30 April 2022.

Source: Based on energy tokens issuers' websites.

The study is based on a group of nine energy tokens. Table 3 presents their characteristics specifying the type of issuer, services offered, availability, etc., as well as their market capitalisation value, and describing their essence. Data for the analysis was obtained from CoinMarketCap and CoinGecko portals, while detailed information on the tokens was collected from the websites of their issuers. Detailed descriptions of the energy tokens and the technical solutions used are also described in detail in: (Andoni et al., 2019; Varnavskiy et al., 2018; SolarPlaza, 2018; PWC, 2018).

The list of energy tokens presented in Table 3 allows several observations to be made:

– in most cases energy tokens have the nature of payment tokens—with their help individual energy producers and energy buyers can make settlements without an intermediary which can reduce the cost of electricity; others allow for the self-creation of tokens by entities interested in using the created blockchain or decentralised applications (DApps), or even the creation of coins thanks to charging electric vehicles from a specific network;
– the first tokens of this type appeared in 2017 and the dominant part of them was implemented a year later; two of them were launched only in 2020;
– the majority (six out of nine) of the surveyed energy tokens are native tokens, meaning that their issuers have created their own blockchain—the others were based on Ethereum (non-native tokens);
– market capitalisation of the researched tokens is very diverse and very variable—from a few hundred thousand USD to almost 200 million. In April 2022 the average value of the market capitalisation of all energy tokens, as reported on the aforementioned portals, amounted to approximately USD 500 million with the daily turnover exceeding USD 50 million.

It is therefore clear to see that most of the instruments described are of payment or use character which definitely defines the nature of their users (buyers). In such an approach the valuation of these instruments is highly difficult, as it is subjective in nature to value access to some service, or the possibility of relatively cheaper acquisition or disposal of energy, or to value the "utility" of owning a token that has created capital for the creation of renewable energy sources, or to value the possibility of creating one's own DApp.

In the era of progressive changes related primarily to the greater digitalisation of modern life the change in investor behaviour, including a greater interest in acquiring digital and at the same time alternative instruments, with their greater availability and lower transaction costs compared to classical financial instruments, the acquisition of energy tokens may represent an alternative for the investor. Of course valuing his satisfaction resulting from the fact that he allocates his resources to finance environmentally friendly actions is highly difficult due to its subjective nature. However, evaluation from the point of view of financial investment is most possible and objective, too.

The fundamental research on energy tokens undertaken by the authors concerns in particular the following:

- analysis of profitability, risk and investment efficiency of tokens in the light of classical measures used by investors;
- the correlation between the returns of the tokens under study (intra-group), as well as between the returns of these tokens and selected stock indices.

The authors have attempted to apply classical investment measures, including in particular profitability, risk and efficiency to the verification of the tokens under analysis. Such a look at energy tokens leads to an assessment of their investment attractiveness from the perspective of portfolio analysis. By investment attractiveness of a particular instrument the authors understand its high expected return and low risk (low volatility of returns)—according to the portfolio theory of Markowitz (1952). Investment efficiency will be considered in terms of reward-to-variability, as the relationship between the above categories, according to the commonly used concept, formulated by Sharpe (1966, 1994).

Although in the literature it is possible to find a study of the risk of investing in tokens (initial coin offerings—ICOs) using the Value-at-Risk methodology (Kuryłek, 2020, pp. 512–530) or the systematic risk studies of investing in coins in comparison to the other investment instruments (Barbu, Boitan, & Cepoi, 2022, pp. 29–49), in this study the authors focused on classical risk measures such as standard deviation of returns which to the best of the authors' knowledge no one has done before.

The study conducted concerns the energy tokens characterised above for the period from 12 November 2017 to the end of April 2022 (i.e. from when they were listed on the indicated information platforms).

To measure their investment attractiveness in a comparative manner research was also conducted on:

- the major cryptocurrencies (Bitcoin (BTC) and Ethereum (ETH)),
- indices of the largest world stock exchanges (American: SPX, DJI, Brazilian: BVP, British: FTM, German: DAX, French: CAC and Japanese: NKX),
- and for alternative commodity investments (gold price (XAU) and WTI-NYMEX crude oil price (CL.F)).

Weekly logarithmic returns were determined for the investment evaluation of the tokens (definition of return attached in the appendix). The choice of such an interval was dictated by the need to standardise the frequency of data—in the case of stock market indices a week is, in principle, five days long, while in the case of tokens, data are available on each day of the week.

In addition to examining the investment attractiveness of energy tokens the authors also looked at the relationship between their returns and those of stocks and commodities, because for investors who want to diversify their portfolio and make it resilient to changes in the economic situation, it is also important whether the prices of the assets held are correlated with each other—how strongly and in what direction. Therefore, the next study undertaken is an analysis of the correlation of the returns of tokens, stock indices and commodities.

3. Research results

For each considered token, stock index and commodity price the following measures of investment attractiveness were determined (Table 4) (definitions of applied measures attached in the appendix):

- profitability, determined as the arithmetic average return,
- risk, described by the standard deviation of the returns,
- effectiveness, calculated with the Sharpe ratio (quotient of average return and standard deviation of returns—the value of risk-free rate was omitted in the Sharpe ratio calculation due to the effectively zero interest rates occurring in the analysed period).

For easier reading tokens are marked in bold and shaded, cryptocurrencies in bold, stock indices in italics, and commodity prices without distinction (this also applies to the next table). The measures presented in the table indicate significant variation in profitability, risk and efficiency of the instruments studied. In addition, unlike indices, commodities and BTC and ETH, some tokens are new instruments and therefore have not been traded in the entire period since November 2017. To highlight this fact the Table 4 notes the number of weeks from April 2022 backwards for which data was available.

Table 4 despite providing detailed information on the measures described does not facilitate the drawing of synthetic conclusions. Therefore, on the basis of this data an investment ranking was made in the indicated three criteria and its results are presented in Table 5. The places in the ranking mean respectively the highest profitability, the lowest risk and the highest efficiency of a given token, stock index or commodity.

The results of the study clearly show that—in light of the investment measures used—most energy tokens perform worse than investments in stocks or commodities. The only exception to the list is the Energy Web Token which is characterised by above-average profitability and efficiency, but its case should be analysed with great caution due to its shortest period on the market. POWR and GRID Tokens were also characterised by high profitability, however, they both occupy the last places in the risk ranking. The study showed that even during such a turbulent time—the COVID-19 pandemic period—the stock and commodity markets were characterised by lower risk than investments in cryptocurrencies and the energy tokens under study.

In addition to examining the investment attractiveness of energy tokens, another part of the study examined the relationship between their returns and the

Table 4. Investment measures of energy tokens against selected cryptocurrencies, stock market indices and commodity prices

Energy tokens	POWR	EWT	WOZX	GRID	CHG	SNC	WPR	ELEC	TSL		
Number of weeks under study	232	107	71	232	181	231	219	213	225		
Profitability	0.0055	0.0193	–0.0442	0.0009	–0.0039	–0.0031	–0.0194	–0.0192	–0.0267		
Risk	0.2023	0.2006	0.1603	0.2845	0.6824	0.1816	0.1842	0.2226	0.2444		
Effectiveness	0.0272	0.0964	–0.2755	0.0033	–0.0056	–0.0170	–0.1056	–0.0861	–0.1093		
Cryptocurrencies / stock indices / commodities	**BTC**	**ETH**	*SPX*	*DJI*	*BVP*	*FTM*	*DAX*	*CAC*	*NKX*	XAU	CL.F
Number of weeks under study	232	232	232	232	232	232	232	232	232	232	232
Profitability	0.0082	0.0096	0.0022	0.0016	0.0019	0.0002	0.0003	0.0009	0.0008	0.0018	0.0025
Risk	0.1133	0.1457	0.0274	0.0293	0.0343	0.0291	0.0314	0.0304	0.0298	0.0190	0.0663
Effectiveness	0.0726	0.0661	0.0792	0.0541	0.0542	0.0062	0.0102	0.0285	0.0258	0.0940	0.0380

Source: Own calculations.

Table 5. Investment ranking of energy tokens and selected cryptocurrencies, stock indices and commodity prices

Rank	Profitability	Risk	Effectiveness
1	**EWT**	XAU	**EWT**
2	**ETH**	*SPX*	XAU
3	**BTC**	*FTM*	*SPX*
4	**POWR**	*DJI*	**BTC**
5	CL.F	*NKX*	**ETH**
6	*SPX*	*CAC*	*BVP*
7	*BVP*	*DAX*	*DJI*
8	XAU	*BVP*	CL.F
9	*DJI*	CL.F	*CAC*
10	**GRID**	**BTC**	**POWR**
11	*CAC*	**ETH**	*NKX*
12	*NKX*	**WOZX**	*DAX*
13	*DAX*	**SNC**	*FTM*
14	*FTM*	**WPR**	**GRID**
15	**SNC**	**EWT**	**CHG**
16	**CHG**	**POWR**	**SNC**
17	**ELEC**	**ELEC**	**ELEC**
18	**WPR**	**TSL**	**WPR**
19	**TSL**	**GRID**	**TSL**
20	**WOZX**	**CHG**	**WOZX**

Source: Own elaboration.

returns of stocks and commodities. This issue is crucial for investors who want to diversify their portfolio and make it resilient to economic fluctuations. It is therefore important whether the prices of the assets held are correlated with each other—how strongly and in what direction.

The values of the Pearson correlation coefficient between the returns of tokens, stock indices and commodities were determined for the available data (respectively, the number of weeks of trading of a given token indicated in Table 4). The matrix of the correlation coefficient value is presented in Table 6 with bold highlighting those values where there is statistical significance of the relationship for a significance level of 0.05; while grey highlights those values where the *p*-value is below one per mille, indicating a strong correlation.

Generally, the results indicate rather weak correlation between the returns of energy tokens and stock market indices, gold and oil prices. This means that the markets for these instruments are not strongly correlated which is an ad-

Table 6. Values of the correlation coefficient between the returns of energy tokens, cryptocurrencies, stock indices and commodity prices

	POWR	EWT	WOZX	GRID	CHG	SNC	WPR	ELEC	TSL	BTC	ETH	SPX	DJI	BVP	FTM	DAX	CAC	NKX	XAU	CL.F
POWR	1.0000																			
EWT	**0.3787**	1.0000																		
WOZX	**0.3689**	**0.4869**	1.0000																	
GRID	**0.4261**	**0.2183**	0.2045	1.0000																
CHG	0.0783	0.0753	0.0954	−0.0320	1.0000															
SNC	**0.5667**	**0.3659**	**0.2466**	**0.2840**	0.0903	1.0000														
WPR	**0.5917**	**0.3516**	**0.3668**	**0.3030**	−0.0208	**0.5344**	1.0000													
ELEC	**0.4221**	**0.3148**	0.1013	**0.2704**	0.0145	**0.4372**	**0.4902**	1.0000												
TSL	**0.3627**	**0.2122**	0.1584	**0.2328**	−0.0341	**0.3272**	**0.4016**	**0.3263**	1.0000											
BTC	**0.5749**	**0.4625**	**0.2415**	**0.3569**	0.0239	**0.6296**	**0.6001**	**0.4436**	**0.3767**	1.0000										
ETH	**0.6305**	**0.4944**	**0.3297**	**0.4546**	−0.0299	**0.6154**	**0.6122**	**0.4652**	**0.3827**	**0.7668**	1.0000									
SPX	**0.1552**	0.1776	0.1345	**0.2252**	−0.0153	**0.1514**	**0.1992**	0.1009	0.1116	**0.1935**	**0.2910**	1.0000								
DJI	**0.1466**	0.1673	0.1328	**0.2252**	−0.0103	**0.1372**	**0.1990**	0.0869	0.1085	**0.1828**	**0.2727**	**0.9712**	1.0000							
BVP	**0.1556**	0.2795	−0.0581	**0.2120**	−0.0359	0.1173	**0.1616**	0.0806	0.1285	**0.1911**	**0.2494**	**0.6565**	**0.6767**	1.0000						
FTM	**0.1903**	0.2521	−0.0215	**0.2552**	−0.0360	**0.1684**	**0.2074**	0.0801	**0.1470**	**0.2233**	**0.3031**	**0.7808**	**0.8044**	**0.6413**	1.0000					
DAX	**0.2200**	0.1991	−0.0757	**0.3050**	−0.1308	**0.1557**	**0.2796**	0.1015	**0.1333**	**0.2653**	**0.3323**	**0.7281**	**0.7487**	**0.5886**	**0.8659**	1.0000				
CAC	**0.2025**	0.1518	−0.0567	**0.2861**	−0.1035	**0.1727**	**0.2791**	0.0700	0.1270	**0.2651**	**0.3334**	**0.7043**	**0.7286**	**0.5799**	**0.8591**	**0.9536**	1.0000			
NKX	**0.1649**	0.1643	0.1097	**0.2002**	−0.0088	**0.1699**	**0.2714**	0.1155	0.1207	**0.1866**	**0.2447**	**0.7150**	**0.7245**	**0.5410**	**0.7377**	**0.7462**	**0.7601**	1.0000		
XAU	0.0653	0.0858	−0.1173	**0.1478**	−0.0269	**0.1566**	0.0710	0.0801	**0.1388**	**0.1734**	**0.2158**	**0.2373**	**0.2468**	**0.2531**	**0.2392**	**0.1728**	**0.1325**	**0.1709**	1.0000	
CL.F	**0.1428**	0.0449	0.0049	**0.1356**	−0.1379	0.1104	**0.1802**	0.0765	0.0729	**0.1832**	**0.1902**	**0.3573**	**0.3661**	**0.3880**	**0.3019**	**0.2843**	**0.2762**	**0.2507**	**0.1460**	1.0000

Source: Own calculations.

vantage for an investor wishing to diversify his or her portfolio and make it resilient to economic changes. Additionally, the energy tokens analysed do not show very strong intra-group linkages—the exceptions being EWT, POWR and GRID tokens where linkages with some other tokens are noticeable. Importantly some of the tokens also do not show links to the key cryptocurrencies, Bitcoin and Ethereum, which may be due to the fact that many of them are based on separate blockchains.

Conclusions

The considerations on tokenization in the field of climate and energy policy presented in this study have allowed the authors to formulate a number of conclusions of a theoretical and practical nature.

Taking into account the ongoing climate changes the authors point to the key role of the state and international organisations in this process. The considerations made at the beginning clearly indicate that common resources, including water, air, solar energy, land should be the subject of state interest and providing society with access to these resources in the modern economy has become a public good. Therefore, the provision of such a good should be financed similarly to other public goods.

This does not mean that private entities do not have the possibility to care for the environment. On the contrary in addition to taking action to reduce the burden of our daily lives on the environment it is also possible to use modern technologies including blockchain technology to solve environmental problems.

One possible action is to use tokenization in solving energy problems. Energy tokens on the market allow for energy settlements, in particular between private buyers and providers (prosumers), financing the creation of their own renewable energy sources, or creating own DApps (Decentralised Applications).

The valuation of the environmental benefits of acquiring energy tokens remains a subjective issue. These benefits may have a financial dimension in the form of lower costs of electricity generation or a more attractive form of its sale by individual small producers bypassing the intermediary. It may be possible to calculate these benefits for an individual user but the benefits depend on many individual characteristics—how much energy the user buys/sells, in what cycles and finally on whether he or she can derive any tax benefits from it. It is even more difficult to assess the value of non-financial benefits such as the satisfaction of doing something good for the environment.

Despite this, the authors have attempted to evaluate energy tokens from the point of view of their investment attractiveness. Obviously, apart from their clearing and utility values, the buyer of such a token may treat it as an alternative investment instrument. However, the results of this research indicate the low investment attractiveness of the tokens in question. Compared to investments in stock or commodity markets or even to investments in major cryptocurrencies such as Bitcoin and Ethereum investments in energy tokens are characterised by relatively lower profitability and higher risk, which from the point of view of investment efficiency, measured using the Sharpe ratio, places them lowest in the prepared ranking here. This research may therefore indicate that purchasers of energy tokens should not be driven by investment and speculative motives but rather by the desire to obtain a means of clearing energy trading, or other utility.

Appendix

Measures used in the paper:

- weekly logarithmic return (used to measure investment performance of each token and comparative asset):

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right)$$

  where:

  P_t – asset's price in *t* period,

  P_{t-1} – asset's price one week before period *t*;

- arithmetic average return:

$$\overline{R} = \frac{\sum_{t=1}^{n} R_t}{n}$$

  where *n* – number of periods;

- standard deviation of the returns:

$$\sigma = \sqrt{\frac{\sum_{t=1}^{n}(R_t - \overline{R})^2}{n}}$$

- the Sharpe ratio (the value of risk-free rate (R_f) was omitted in the Sharpe ratio calculation due to the effectively zero interest rates occurring in the analysed period):

$$Sharpe\,ratio = \frac{\overline{R} - R_f}{\sigma}$$

- Pearson correlation coefficient:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \overline{y})^2}}$$

  where *x* and *y* stay for returns of two different tokens / assets.

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