Foreword

Bochum University of Applied Sciences has identified the central transformation topics of sustainability and digitalisation as a key goal and anchored them in its strategy. In several study programmes, students are already being prepared and qualified as future experts for their tasks as agents of change in the transformation process. Numerous teaching and research projects deal with specific sustainability questions, which increasingly makes Bochum University of Applied Sciences a lighthouse for sustainability projects with an international orientation. The importance of digitalisation for solving future sustainability challenges is clearly becoming the dominant factor. In its report *Our Common Digital Future*, the *Advisory Council on Global Change (WBGU)* emphasises that digitalisation must be designed in such a way that it can serve as a lever and support for the Great Transformation towards sustainability and can be synchronised with it.

In this context, technological approaches and use cases from the areas of blockchain and decentralized finance are prominently discussed in the public debate and are still controversial with regard to their contribution to sustainable development. The researchers of the *Sustainable Technologies Laboratory (STL)*, a research institution of this university with a focus on the analysis and evaluation of technological solutions to questions of sustainability, have therefore organised the second international symposium *smart:sustainable: Blockchain & Decentralized Finance - Opportunities for Sustainable Development* with students in July 2021. Within this event, international experts from practice and research were invited to give parallel workshop sessions together with students to deepen their knowledge based on concrete questions. Also, the results of the seminar *Sustainability in Technology*, with student papers that were presented within the symposium, make it clear that blockchain and decentralized finance have great potential for realising sustainability effects, as long as they are consistently designed under sustainability criteria. The students' main topics were blockchain use cases on gender inequality, impact investment and local cryptocurrencies for communities in developing countries.

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Blockchain for Impact Investments: a Sustainability Assessment Framework on Six Use Cases

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Abstract – The 21st century is a century marked by excessive challenges regarding sustainability issues. Because currently technologies are being discussed as solutions for achieving and funding the Sustainable Development Goals (SDGs), this paper deals with the topic of blockchain technology for use in impact investments and aims to assess the implementation of the technology from a sustainability perspective. This paper identifies six use cases that involve blockchain technology as an impact investment strategy. To assess these use cases in an exemplary manner, we have developed a conceptual sustainability assessment framework. This framework allows us to evaluate blockchain technology implementation from a sustainability perspective in a holistic context. In doing so, our results not only show how the different blockchain technologies are already being used in the field of sustainability, but also how much progress has been made and what hurdles still need to be overcome. The statements that can be derived from this can make a major contribution to the public discourse on the sustainability of blockchains, which can be used not only for informing stakeholders, but also for optimizations and further progress on implementations of the technology.

Keywords – blockchain, impact investments, sustainability assessment, sustainable development goals

1. Introduction

The 21st century is a century in which global challenges have never before been more evident or perceptible. It is a century marked by climate change, irreversible interventions in ecosystems, loss of biodiversity, and ever-increasing social conflicts. Because of this, one of the greatest and most critical challenges societies are facing today, is how to transform themselves to achieve sustainable development. The change needed extends across the ecological, economic, and social dimensions of sustainability (Kropp, 2019). For instance, we need to emit less greenhouse gas emissions, achieve intra- and intergenerational equality, promote more sustainable lifestyles, take care of the planet, and ensure that all people live safe, healthy, and financially stable lives.

The need for change has also been recognized in the global arena. In 2015, the United Nations (UN) adopted 17 Sustainable Development Goals (SDGs), that can be understood as a universal call with the aim to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity by 2030 (United Nations Development Program, n.d.). To ensure that these goals are achieved, there is an urgent need to assess how to finance the necessary societal transformations. In this respect, the SDGs offer a kind of framework for investors and corporations to follow for making investments and instigating other activities, and this has incited growth in impact investing: a type of investment that seeks both financial return as well as a positive social and ecological impact. However, there are many barriers that prevent these kinds of investments from being realized at a larger and necessary scale (Uzsoki and Guerdat, 2019).

In present-day discourse, technology shows great potential in contributing to the funding and achievement of the SDGs (Berawi, 2017; Imaz and Sheinbaum, 2017; Walsh et al., 2020). Specific to the topic of impact investments, blockchain technology enables new opportunities to scale up impact investing globally (Uzsoki and Guerdat, 2019). This technology has gotten a lot of attention in the last few years due to cryptocurrencies such as Bitcoin (Urquhart, 2018). In fact, many projects and organizations use blockchain technology for impact investing (Uzsoki and Guerdat, 2019). However, this technology, and especially Bitcoin, has been criticized for its high energy use (De Vries, 2018), which raises the question, whether the technology is suitable for the purpose of impact investing. For example, the annual carbon footprint of Bitcoin amounts for 66.43 Mt CO_2, which is comparable to the annual carbon footprint of Israel. Also, a single Bitcoin transaction amounts for 848.35 kg CO_2, which is equivalent to the carbon footprint of 1,880,230 VISA card transactions or 141,391 hours of watching YouTube (Digiconomist, 2021a).

When analyzing and evaluating sustainability aspects of blockchain technology, CO_2 emissions or energy consumption are usually mentioned as the only sustainability factors. However, sustainability is more than that, although it is doubtlessly an important factor to consider. From this point of view, the research field of blockchain and sustainability (and in this specific case: impact investments) is missing a framework that can assess the sustainability of the implementation of blockchain technology more comprehensively, instead of only focusing on emissions or energy use. Based on this, we developed a conceptual sustainability assessment framework, which contains indicators and sub-indicators that we found to be relevant for a sustainability assessment. These indicators are based on well-known concepts of sustainability, criteria from impact measurements, as well as our own knowledge regarding the topic. Within the background of this sustainability assessment framework, we aim to answer the following research question: *Where is blockchain technology used for impact investments so far, and how can this implementation be evaluated from a sustainability perspective?*

This research question will be answered based on six use cases, which are all projects that encourage sustainable and impact-oriented investments. We chose these use cases based on a literature review on the topic of blockchain and impact investments and implemented these within the framework to exemplify how it works. Moreover, we will describe how we developed and evaluated the framework. We also present our methodology and the results of the use cases. As an outcome, we discuss the possibilities and hurdles of our framework and provide an outlook for the future.

2. Theoretical Background

Due to the thematic focus on projects for sustainable and impact-oriented investments, these two terms need to be defined and explained in order to understand their relevance in the given context. As the need for financing the achievement of the SDGs was already mentioned in the introduction, the phrase "money makes the world go round" appears to be very accurate. The UN estimates that the total amount of investments needed to achieve the SDGs are between 5 trillion and 7 trillion USD per year (Uzsoki and Guerdat, 2019). Especially developing countries have estimated a financial gap of 2.5 billion USD per year for sustainable development. Fortunately, impact investments have received a great deal of attention in the past decades, and they have increased tenfold in five years (Uzsoki and Guerdat, 2019). Nevertheless, what exactly is meant by sustainable and impact-oriented investments? In general, these are terms used to describe investments with a social, ethical, and environmental focus to generate a positive, measurable, social and environmental impact alongside a financial return (Forum Nachhaltige Geldanlagen, n.d.). In the literature, there are countless other terms, which are often used as synonyms, and which make a comprehensive overview difficult. What they all have in common is their shared focus at the social, ethical and environmental levels to generate positive and measurable impacts in these areas. For this reason, the term impact investments will be used comprehensively for all terms relating to this theme in this paper. In addition to different terms, impact investments can also differ in their form, and thus, the strength of their impact.

The first area of investments is traditional investing, where a social and environmental impact is limited or not at all considered. The goal is financial profits without taking ESG (environment, social, governance) factors into account (Uzsoki and Guerdat, 2019). The second area is responsible investing. Here, exclusion criteria are determined to help identify projects, companies or products that are not complying with the requirements or even violate the defined and specified norms and standards. Furthermore, sustainable investments can be identified as investments that are mainly driven by sustainable factors or themes such as carbon footprint, gender equality, waste reduction or climate change, urbanization, and population growth. Another form of investment strategy is philanthropy, which is a way of making investments for a positive impact without the aim of a financial return discussion shows the complexity of the underlying topic, but also its relevance regarding sustainable development.

3. Methodology

This paper is based on the research question, *Where is blockchain technology used for impact investments so far, and how can this implementation be evaluated from a sustainability perspective?* To answer this, we used an extensive literature review to identify relevant use cases where blockchain technology is being used for impact investments. Furthermore, we developed a sustainability assessment framework to assess these use cases under a sustainability perspective.

The literature review for the topic of the use of blockchain technology for impact investing was conducted using the keywords "blockchain and sustainability", "blockchain for impact investments", and "Distributed Ledger Technology (DLT) and impact investments" in an extensive internet research. The results provided us with various articles and blog posts about projects and organizations using blockchains for impact investments. We selected these projects based on the available data, information, and the specifics in the context of sustainability. This selection was in general very limited. Finally, we chose three projects with sustainable cryptocurrencies (Fishcoin, SolarCoin, and BitGreen), as well as three other projects that use blockchain technology for facilitating sustainable process or goal optimization in their work (Moeda, Plastic Bank, and Energi Mine) (LeafScore, 2021; Uzsoki and Guerdat, 2019). Short explanations of each of these projects are listed in Table 1.

Table 1: Descriptions of the use cases (LeafScore, 2021; Uzsoki and Guerdat, 2019). *Logo references:* (BitGreen, n.d.; businesswire, 2021; CoinMarketCap, n.d.; Fishcoin, n.d.; Pitchero, 2017; Solarcoin, n.d.).

Projects	Logo	Description
Fishcoin	Fishcoin PROJECT	Fishcoin aims to improve the sustainability of seafood supply chains by incentivizing data capture and sharing on a blockchain at every step.
SolarCoin		SolarCoin is a digital asset, which aims to incentivize solar energy production and accelerate the global energy transition by increasing returns on investment and decreasing payback time.
BitGreen	BitGreen	The cryptocurrency BitGreen focuses on rewarding people for decisions that reduce their carbon footprints, such as volunteering, recycling, composting, or using a local bike-sharing program.
Moeda		Moeda is a cooperative investment platform connecting underbanked community-owned enterprises with impact investors from around the world, who can directly invest with the flexibility of digital tokens and the possibility to track their impacts.
Plastic Bank	plasticbank	Plastic Bank is a plastic offset program that uses tokens and digital wallets to promote financial inclusion of the poorest while contributing to the circular economy by rewarding the collection of plastic waste.
Energi Mine	energimine	Energi Mine is a decentralized market for energy that uses advanced technologies such as AI and blockchain to sustainably manage energy and incentivize energy-saving behaviours through the EnergiToken.

To assess the sustainability of these use cases, we have developed our own conceptual sustainability assessment framework. This framework contains relevant indicators and sub-indicators based on well-known concepts of sustainability, criteria from impact measurements, and our own knowledge regarding this topic.

In the context of sustainability concepts, we have focused on the Three Dimensions Model, in which sustainability is reflected in the three dimensions: ecological, economic, and social. A move toward a possible valuation and weighting is based on the globally recognized model of strong sustainability, whereby the ecological dimension is seen as the basis for the development of the other dimensions. In this model, natural capital cannot be replaced by other forms of capital from other dimensions (Landesarbeitergemeinschaft Agenda 21 NRW e.V., n.d.). The dimension of ecology addresses environmental issues, including the long-term conservation of natural resources, and it is often exemplified by an emphasis on environmental protection. The social dimension involves people and society, with a particular emphasis on aspects of fairness, equality, and well-being. The economic dimension focuses on the long-term preservation of economic power, yet this kind of economic return entails a separation from steady economic growth, since steady economic growth is also accompanied by an overexploitation of resources (Landesarbeitergemeinschaft Agenda 21 NRW e.V., n.d.).

Furthermore, already existing concepts and frameworks regarding impact measurements in the management approach were helpful for identifying relevant indicators. However, it should be added that non-financial indicators in particular are also oriented here towards the three dimensions of sustainability, the ESG criteria (environment, social, governance) or, alternatively, the SDGs (Youmatter, 2020).

Another tool for the development of this framework was a preliminary literature review for the use cases, from which we were able to identify other relevant indicators for the sustainability assessment. In particular, the individual features mentioned in each project were identified as possible further indicators. We categorized the indicators that emerged according to the three dimensions of sustainability (ecological, economic, and social) (Kropp, 2019) and added a further category called "Further indicators". This additional category includes further measures that could not be allocated to the other categories. Nonetheless, these are also very important for a scientific and meaningful sustainability assessment. The indicators that were used are shown in Figure 1.

Categories	Indicators	Sub-Indicators
Ecological		
	Environmental impact	Electricity mix
		Energy consumption / year
		Energy consumption / transaction
		CO2 Footprint / year
		CO2 Footprint / transaction
	Contains actions for climate protection	
	Includes actions to protect ecosystems	
	Facilitates sustainable actions	
Social		
	Promotes awareness of sustainability	
	Focuses behavioral changes for more sustainability	
	Promotes gender equality	
	Promotes equity	
	Promotes independence and autonomy of stakeholders	
	Enables participatory processes	
	Employment	
Economic		
	Fair return on investments	
	Profits for operators and stakeholders	
	Considers given infrastructure and resources as well as general possibilities	
Further Indicators		
	Characteristics	Blockchain technology
		Consensus mechanism
		Transactions per second (TPS)
	Enables further process-oriented actions for the promotion of sustainability	
	Availability of scientific research	
	Promotes transparency	
	Relevance of addressed topic	
	Measurement of the impact	
	Good solution for a relevant problem	
	Addressing the topics of SDGs	Total of 17

Figure 1: Criteria of our sustainability assessment framework.

The indicators in the field of ecology aim at environmental protection or a reduction of the degree of environmental degradation. One relevant aspect in the context of ecological impact is therefore the energy consumption of the technology (Sedlmeir et al., 2020). This in turn is based on the energy mix used, which accordingly represents a relevant sub-indicator in the environmental context. It is also a special case because we are talking about a decentralized system where computers and servers can be located anywhere. To show the difference and relevance of the indicator we looked up three examples of energy mixes. Table 2 shows the different energy mixes in the countries of Germany (Strom-Report, 2021), Kazakhstan (Schlumbohm et al., 2021), and China (China Energy Portal, 2020) regarding their composition of fossil fuels, renewable energies and even nuclear energy in percent. It becomes clear that the energy composition varies from country to country, which leads to the conclusion that the sustainability impact varies greatly, depending on the location of the computers and servers. Therefore, ecological influences cannot be generalized, but rather they must be determined individually for each location.

Other sub-indicators are the electricity consumption as well as the transaction and the resulting CO_2 emissions per year, which give an overview over the total amounts this technology is using. The other indicators in the ecological dimension aim to reveal what direct and positive impacts the use cases have in the context of sustainable actions, or to what extent they facilitate these.

The category of social dimensions contains indicators regarding the social requirements of the use cases. These indicators are used to examine to what extent projects meet general social requirements, such as gender equality or equity. Also, they examine to what extent relevant stakeholders are involved and whether future independence, thus autonomy, of the people is promoted. Another indicator is “Employment”, which reflects on people’s working conditions and their financial opportunities to create a better life. Furthermore, we also took the indicator, “Promotes sustainability awareness”, into account. This is important in order to achieve sustainable development, because the required long-term behavioral changes go hand in hand with an understanding of the fundamental issues and challenges (Milke and Rostock, 2013). The related measure, explicit education, is called “Education for Sustainable Development” (ESD), which not only imparts sustainable knowledge, but also connects different disciplines regarding the aim of a sustainable future (Bundesministerium für Bildung und Forschung, n.d.). We therefore checked to see whether the use cases gave detailed information and explanations with the goal of understanding their actions within a sustainability context.

Table 2: Electricity consumption in Germany (2020) (Strom-Report, 2021), Kazakhstan (2018) (Schlumbohm et al., 2021) and China (2019) (China Energy Portal, 2020).

Country	Composition	Percentage
Germany (2020)	Fossil fuels	49%
	Renewable energy	51%
Kazakhstan (2018)	Fossil fuels	97%
	Renewable energy	3%
China (2019)	Fossil fuels (coal, gas, oil, biomass)	69%
	Nuclear energy	5%
	Renewable energy	26%

The category of economic dimensions contains indicators such as “Fair return on investments” and “Profits for operators and stakeholders” to look at the financial realities from both sides: the funders and the actors. Although we placed a strong focus on the environmental influences within the framework of the evaluation, economic indicators also need to be included as well. The reason for this is the underlying economic growth and social system, which cannot function without monetary means. The UN attributes a much higher relevance to the financial aspects of sustainable development, which was already discussed in the introduction (Uzsoki and Guerdat, 2019). In the area of use cases, this relevance is also given. Investment returns determine the attractiveness of investments for investors, that is, if and how much they want to invest. This is particularly relevant for the fundamental existence of a use case. Also, the financial return for actors who perform certain actions is relevant in the context of the engagement of the project, the success, and the actual impact on sustainability.

The last category, “Further indicators”, starts with the technological characteristics of the use cases, where the general blockchain technology, the consensus mechanism, and the transactions per second (TPS) are addressed. We considered these aspects in our framework because the technological conditions have a major influence on the environmental impact of the use cases. Technology and consensus mechanisms are particularly decisive for energy consumption. In our case, we assumed that a higher TPS is a lot more energy efficient, because more transactions can be done in a shorter time compared to other consensus mechanisms with a lower TPS. To exemplify this, for 100 transactions, an Ethereum blockchain needs four seconds for these transactions to be made, whereas an IBM blockchain can be done it in less than a second (Krisha, 2021; Raczyński, 2021; Sedlmeir et al., 2020). This reduces the overall energy required, which is why our assumption is that it is more energy efficient, because the amount of work can be done in less time.

Further indicators, which aim at additional characteristics of the use cases, are for example transparency, whether further process-oriented actions are possible, and if a measurement of influence was implemented in the use cases.

Likewise, our framework has the claim to derive an objective evaluation. However, this creates an issue for the indicators “Relevance of addressed topic” and “Good solution for a relevant problem”, because the assessment of these indicators can be highly subjective. For example, someone may consider reduction of plastic waste as an important sustainability issue, whereas someone else sees gender equality as the most important tool in achieving sustainable development. We solved this problem by always evaluating the use cases from the point of view that every topic is equally important. However, some of the use cases focus on direct actions for sustainable development, financial support and raising sustainability awareness, which we consider as especially urgent for achieving the SDGs, and thus, somewhat more important.

Additionally, the availability of scientific research as well as the number of addressed SDGs was evaluated within the framework. In the end, the scientific nature of the information analyzed is crucial for the quality of a sustainability assessment. Likewise, the SDGs deliver solid indicators on the evaluation on to the extent to which the use cases contribute to sustainable development.

With the help of an extensive literature review and analysis regarding the use cases, we were able to fill in and evaluate these indicators. For a clear and structured presentation of our results, we have created a table in which the assessment and evaluation of the individual indicators is shown in color (see Figure 3).

The legend to these colors can be viewed in Figure 2. The colors range from dark green as very positive to dark red as very negative. In some cases, we did not find the information needed to assess a specific indicator. We solved this by using a dark grey color where no information was available. In some cases, we were able to estimate the possible answer, which we marked with a light grey color and the letter “A” for assumption. Furthermore, it must be mentioned that the results of the framework are made based on estimations and assumptions that we made using the literature available about each project. However, estimations and assumptions like these are always based on the subjective perceptions of the author. After all, the aim of our paper is not to assess these specific projects, but to identify projects that use blockchain technology for impact investments and use these projects to exemplify how a sustainability assessment framework like ours can work.

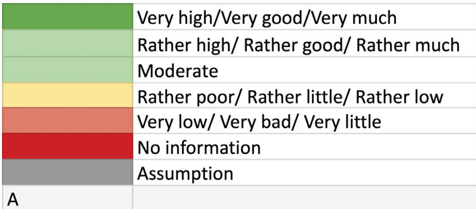

Figure 2: Color legend for the results of the sustainability assessment framework.

4. Results

In this section, we explain the results of our methodology in more detail. During the application of the methodology and due to the underlying research question of this paper, we noticed that we obtained different types of results, which we would like to explain separately. First, under “Results: Methodology”, the results related to the methodology and its application is provided. Here, we elaborate the general results around the framework and the hurdles in its use. Second, under “Results: Use cases”, we focus more on the substantive results of our methodology, because our aim was not only to develop a sustainability assessment framework, but to identify projects that could be applied in it in an exemplary manner at the same time. Together, this section provides the results of the sustainability assessment of six different use cases in the context of blockchain implementation for impact investments.

4.1 Results: Methodology

The results of our sustainability assessment regarding the six chosen use cases can be viewed in Figure 3. The framework presents a wide variety of evaluations, whereby the results differ greatly in some categories. In comparison to the other categories, negative evaluations are clearly more frequent in the social dimension, while strongly positive evaluations are more frequent in the areas of the "Further indicators". The positive evaluations around the relevance of the topic are particularly noteworthy, because it clarifies the reason for the selection of these projects within the framework of sustainable development. It was difficult to determine the energy consumption of the technologies in the use cases, as there was almost no data available. If there was data available, it was only isolated data based on assumptions. For this reason, the data is very similar for almost all use cases (four of them use Ethereum as blockchain technology) or not currently available, especially when it comes to smaller or newer blockchains.

It should be noted that even if there was no direct action on sustainability, each use case enabled or facilitated sustainable action. Direct sustainability awareness was only rarely addressed and must be further developed in all use cases. Social factors were only mentioned by the use cases if the projects showed a particularly positive effect in that area. Participation processes have been established for all use cases because they often depend on the help and active participation of the actors for a successful implementation. It is interesting that the fair returns on investments for investors are not discussed, especially because the projects focus on impact investments. In contrast, the profits are clearly emphasized as advantages and positive aspects. In addition, most of the projects consider local conditions and respond to them accordingly. Often, attempts are made to compensate for this lack of consideration for local settings. For example, Fishcoin addresses the current conditions considering that people in developing countries often do not have a bank account or ID, which makes traditional money transfer useless for them. Fishcoin's solution is to use the devices that almost everyone has in these countries: cell phones. Thus, in cooperation with various mobile phone providers, recharging data plans for collecting and uploading project-related data is offered (Uzsoki and Guerdat, 2019).

Moreover, a widespread basis for the projects mentioned is the Ethereum blockchain. This blockchain is frequently used by the projects we chose for our use cases, but in comparison to newer blockchains, it is not that efficient. This can particularly be seen in the transactions per second.

Certainly, there is much room for improvement, for example, around impact measurements. On the other hand, many challenges such as a lack of transparency are already being addressed in these projects. A big point of criticism, which is also a big challenge for the implementation of the methodology, is the lack of scientific literature, as it is indispensable for a good application and meaningful results. Finally, many evaluations and numbers are based on estimations, assumptions, and less on solid measurements. In summary, we have managed to evaluate use cases according to their sustainability within the framework of the three dimensions of sustainability and beyond.