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Blockchain in the Chemical Industry

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With this paper, we motivate to re-think the impact of blockchain technology on the chemical industry as a case study for many other industries with high capital expenditures. We provide a systematic approach, the value-driven Blockchain in Chemicals (VDBC) framework, to identify and evaluate possible use cases. To demonstrate the application of the framework, we have exemplarily identified seven disruptive blockchain use cases for chemicals.

The original motivation of the blockchain technology

Digital currencies based on the blockchain technology[1] that started with Bitcoin have gained high interest in various sectors. They present ways of digitally transferring value without the usual necessary intermediaries, i.e., clearinghouses, banks, or other service providers. For example, cutting out the intermediaries in money transfer operations alone enables double-digit cost savings in processing fees.

At the same time, inherently digital processes can empower near real-time transactions at marginal cost, which sparks entirely new ways of how value and ownership are transferred between humans or corporations but even down to plants, units, equipment, and machines. This article will not only enable you to think beyond store of value but enable you to come up with ideas that exploit the far greater potential of the blockchain technology to optimize your business processes.

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Blockchain beyond digital store of value

Different to a few years ago, many experts today consider the underlying blockchain technology as the largest potential to disrupt industries far beyond banking. The products of large infrastructure providers (e.g., Microsoft, IBM, SAP), large interdisciplinary consortia[2], venture capital (VC) activities (e.g., Andreessen Horowitz LLC, Digital Currency Group, Robert Bosch Venture Capital), and large amounts of startup funding via the concept of initial token offerings (ICOs) provide an indication that blockchain is quickly taking over various areas. While venture investments have been purely turned to digital currencies related projects up until 2013, flows are now redirected towards blockchain technologies instead of currencies and the finance industry. These are indicators that blockchain projects with the primary focus on general-purpose technology and other applications are on the verge of disrupting other industries instead of being a pure store of value.

Essential features of blockchain for industrial applications

With respect to the chemical industry, we want to emphasize four main blockchain features that can be combined to enable new functionality:

1) Distributed Ledger

2) Trustlessness

3) Tokenization of value

4) Smart Contracts

Distributed ledger: A distributed ledger offers the following advantages over other technologies that support data storage and use: Records are stored in an inherently distributed and truly immutable way, which lowers risk of data losses or manipulation and enables a complete audit trail of necessary properties, production steps, transactions, etc.

Trustlessness: Once in place, ownership of a blockchain can be distributed among the public or consortia, such that no single party can set the rules. Combined with authentication and the ability to provide different levels of access to data, the technology is suitable for sharing a platform or information even between non-trusting entities.

Tokenization of value: Blockchain technology can be used to replicate physical assets in the digital world. Tokens allow for automated governance and enable a seamless distribution of assets across shareholders.

Smart contracts: Smart contracts are code that can be executed on blockchains. Once pre-programmed conditions are met, smart contracts automatically make deterministic changes within the distributed ledger without intermediaries. For instance, consider an automated transaction where the value is transferred once a shipment has been delivered to the buyer.

Even though these concepts may sound rather abstract, in the following it is shown how these essential blockchain features can tear down barriers to market and enable disruption from rearranging processes to the generation of new business models.

Industrial relevance of blockchain technology

The potential impact of blockchains beyond digital currencies is impressive: Reports project efficiency gains ranging anywhere from an estimate of $20 billion per year for payments, trading, and compliance[3] to more than $176 billion per year in business value-add across industries[4].

What is indicated by aforementioned metrics and expert predictions also becomes prominent in tangible use cases from across industries, with few examples given in Table 1.

Table 1

Blockchain applications in various sectors

Sector	Application
Energy	Smart metering combined with blockchain enable P2P marketplaces for rooftop solar energy. Tracking and trading carbon emissions in a transparent and auditable manner.
Health	Storing medical records in order to avoid inconsistent and redundant data handling.
Mobility	Dealer management systems that enable secure data transfer and communication to facilitate tracking for the leasing sector. Direct payment from electric vehicles to charging stations.
Insurance	Fully automated digital insurance contracts that are executed on the blockchain.
Manufacturing	Machine to machine payments. Handling of 3D printing licenses.
Logistics	Improved ownership, identity, and data management across different players across the world.

Facing the disruptive potential of blockchain as well as successful pilots in industries edging the chemical industry, leaders in the chemical industry can no longer stand still.

Building on extensive literature providing an introduction on blockchain technology[5], this working paper guides leaders in the chemical industry through the complicated blockchain world from a business value perspective. We will introduce you to the questions you need to ask, in order to create real value by applying blockchain technologies. Thereafter, exemplary, we will share seven concrete blockchain use cases with the potential to disrupt the chemical industry.

Extended digital transformation in the chemical industry

While for a long time the focus in the chemical industry has been on collecting and using the vast amounts of available data in a more structured and efficient manner, blockchain will enable the next step towards jointly using data with business partners, such as suppliers, customers, equipment manufacturers, etc.

So far, only little scientific research has been conducted on applications close to chemical industry (Sikorski, 2017; Mengelkamp, 2017, SAMPL project[6]). However, there are already companies that stand out in their effort to innovate, one of which is the German chemical company BASF, who is running supply chain pilot projects in cooperation with the startup QuantoZ already since the midst of 2017[7]. Edging the chemicals sector is the field of 3D printing where there are many projects investigating how printing licenses can be efficiently handled[8].

A shift from a technology-oriented to a value-driven approach for blockchain implementation is required

In the following, we present a guide on how leaders in the chemical industry can pilot and implement blockchain technology to test the potential and leverage positive returns. Analyzing multiple blockchain projects across industries, the authors have identified that blockchain applications are largely implemented from a technology rather than business value perspective.

This is driven by blockchain being a hyped technology topic (that most large companies try to apply/sell) as well as a lack of technological understanding among organizational leaders. In the early adopter phase, the application of blockchain for the sake of blockchain is not expedient if not combined with a strong vision and courage for creativeness. The latter two should be the foundation of blockchain projects to reap maximum business value.

The benefits of using blockchain technology are rather of the form of using enterprise resource planning (ERP) software than of big data that can be applied to problems of all scales.

This is because the most significant economic benefits arise when this technology is implemented not as a direct substitution of existing processes but with the goal of rethinking the status quo at a large scale.

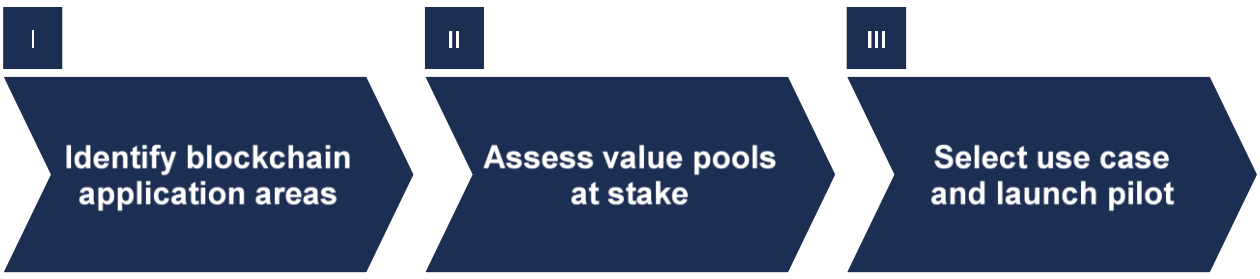
Leaders should launch blockchain pilots where the three technologies enable the highest returns

Our Value-driven Blockchain in Chemicals (VDBC) framework navigates the blockchain applications along the entire chemical value chain.

To identify business value oriented blockchain use cases we recommend the three-step approach shown in Figure 1.

Figure 1

Three-step process for economically efficient application of blockchain



I. First, leverage the following four questions of Dr. Adrian McCullagh's FITS model[9] to identify areas with potential for Blockchain application:

1) Fraud: What kind of business is impossible today due to the lack of trust? Which borders (regional, financial, sectorial) cannot be overcome without guarantees?

2) Intermediaries: Where do you currently need trusted third parties or other forms of intermediaries and where is it possible to eliminate them?

3) Throughput: Which limits that are caused mainly by (necessary) human action should be overcome?

4) Stable data: What kind of recordkeeping would improve from security, immutability, and resilience? How could this be financially rewarding?

The matrix given in Figure 2 can be used as an inspiration of how two areas can be systematically detected.

II. Second, consider the potential to value creation of those application areas. Analyze the capital and operating costs at stake in the identified area of your value chain.

III. Select a blockchain use case and launch the pilot.

When going through this three-step process, scrutinize even the most basic workflows at your company. Try to find use cases that match at least two of the FITS categories.

Once use cases are identified, always keep in mind preferring technologies that best fit to the use case, even if it is not a blockchain technology.

Being an early stage technology topic, quantifying the costs of implementing blockchain use cases along the chemical value chain is rather difficult. Instead of investing in cost estimations, leaders should choose high-value use cases derive a pilot that provides a minimum value and take an agile and experimental approach to implement the first pilot in a sandbox, i.e., run the full application in a limited environment. After having initial prototypes ready, cost estimations are becoming more predictable and a business case for further developments can be derived.

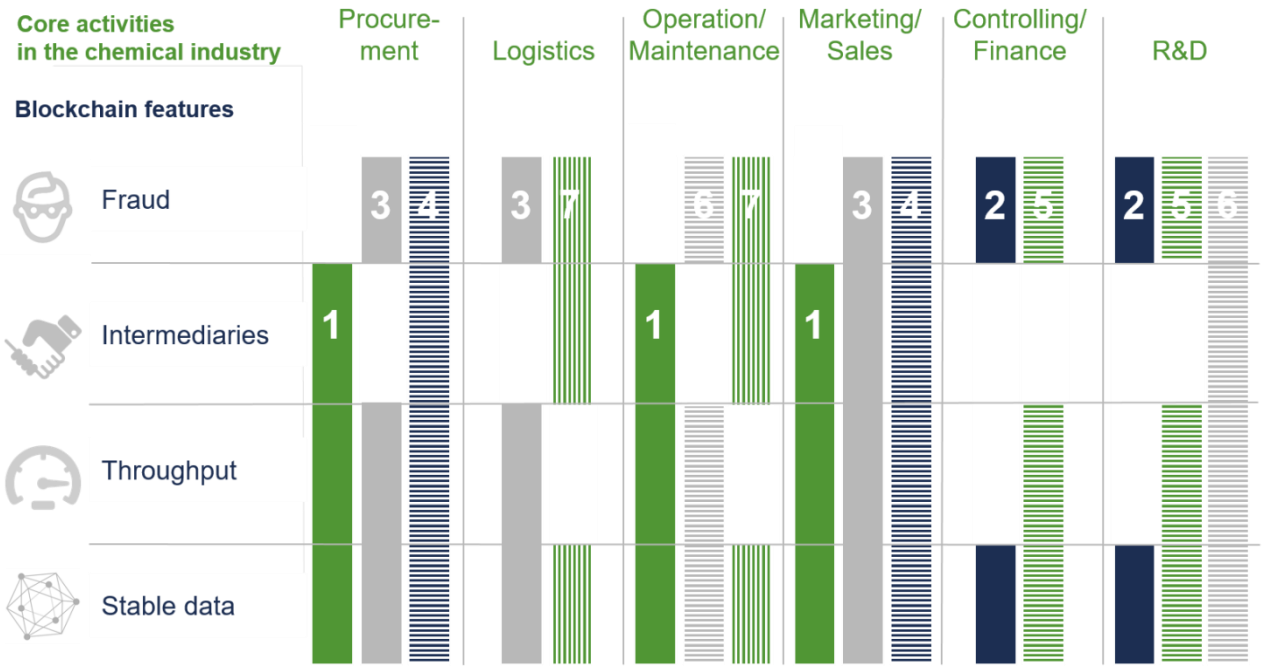
Seven blockchain use cases for the chemical industry provide a starting ground

To give you some ideas to start with, the first step of the indicated process is explained using valuable examples that can, and partially are already implemented with currently available technology. We begin by selecting possible applications along the value chain, which can be seen in Figure 2.

- Use Case 1: Industrial symbiosis – automated contracts for chemical parks
- Use Case 2: Cross boarder payments using digital currencies
- Use Case 3: Supply chain organization – end-to-end serialization
- Use Case 4: Distributed direct sales platform
- Use Case 5: Tokenization of plants/units – shared financing and ownership
- Use Case 6: Internet-of-Things data integrity
- Use Case 7: Corruption free tendering processes

Figure 2

Value-driven Blockchain in Chemicals (VDBC) matrix



1. Industrial symbiosis: procurement, operation, maintenance, marketing, sales

In chemicals, size matters. Larger chemical parks enable synergies such as a shared infrastructure (steam networks, electricity generation, wastewater treatment, etc.) and the use of intermediary as well as byproducts, enables a waste-free production. Tremendous scale benefits drive the many mergers and acquisitions and justify the highly consolidated industry. At the same time, the complexity of large companies sets efficiency at risk.

To balance the benefits of scale and specialized production, current practice is to settle access to the networks via long-term contracts with external service providers (*Intermediaries*) or neighboring companies. This gives certainty for long-term planning but prevents flexible operation and a dynamic adaptation to the significant market changes we are facing today. Long-term contracts without sufficiently dynamic pricing lead to suboptimal operating points of the whole site.

Privacy concerns are the main reason that obstructs a joint optimization of the whole chemical park or at least of the interconnecting networks (compare to 'Fraud' in the aforementioned FITS framework).

The time span between different contracts could be much shorter even when keeping the current practice, but negotiating contracts takes up a lot of time and consumes a lot of money. Not only could the significant costs associated with this inefficiency and complexity of the contract negotiations be saved, but also the margin of the service provider could be distributed between the different companies (*Intermediaries, Throughput*).

We propose to use the agility of smaller organizations and combine it with the theoretical resource efficiency of whole chemical parks by the use of smart contracts that optimize the whole park in a distributed manner by adjusting the prices for the interconnecting streams dynamically. The secure storage of all price calculations makes this process suitable for auditing (*Stable data*).

2. Cross border payments using digital currencies: logistics, controlling, finance

In companies that are doing business all over the world, there is always the challenge that many currencies have to be used. Even though ERP systems help to organize the flows of money, in many cases dealing with different currencies obfuscates the underlying transactions (*Fraud*).

Handling all internal transactions in a company own currency that is recorded on a distributed ledger does not only give high traceability, which can significantly simplify work for accountants, auditors, and managers but also makes services at different locations across the world more transparent (*Stable data*). If you look at R&D units, many companies have several of them spread across the globe in order to use local talent and be closer to where the results are used. Having a currency that makes the price for services comparable helps to distribute the work efficiently.

3. Supply chain organization: logistics, procurement, marketing, sales

One of the most obvious use cases for blockchain application is the efficient management of supply chains. Different partners can access the distributed ledger with the necessary permissions (*Fraud*). The blockchain enables tracking of where (intermediate-) products were produced, which quality standards were applied and where they are on their way to the end customer. Additionally, a blockchain enabled supply chain can handle the complete payment process, including triggering higher fees for the delay, etc. (*Throughput, Stable data*).

4. Distributed direct sales platform: procurement, marketing, sales

Smart contracts enable autonomous sales platforms for (intermediate-) products. Centralized platforms like Alibaba (where chemical products are already traded) are trying to take over customer insights from chemical companies (*Intermediaries*). Decentralized, smart contract enabled sales platforms, on the other hand, allow chemical companies to keep their valuable data and possible implementation of a two-sided marketplace would simplify the work of marketing since supply and demand would be much more transparent (*Stable data, Fraud*).

Since a decentralized sales platform does not necessarily need to make profits, chemical companies can save the margins that the oligopolic platform operators can take. Automating procurement and sales via such smart contracts has the additional benefit that parties of different scales can do business: Managing relationships, pricing, and sales is automated. In combination with suitable logistic partners, large chemical companies can sell their product not only to large buyers and resellers but also to smaller businesses, thus making the market even more efficient (*Throughput*).

5. Tokenization of plants/units: controlling, finance, R&D

As mentioned in the beginning, this new and highly scalable form of distributed tokens can be used for new approaches to financing projects. It not only simplifies the process of selling the shares but also enables new ways to communicate with the owners (*Throughput*). Distributing stocks comes with high administrative efforts to maintain records of your shareholders, how diversified the holdings are, to be able to keep them informed about general assembly, etc. If ownership is distributed and held fully digital, owners of the tokens can access necessary information, maintain their records of information by themselves, and vote on decisions, such as displaying their opinions digitally instead of holding a stockholders' meeting (*Stable data, Intermediaries*).

6. Internet-of-Things data integrity: operation, maintenance, R&D

For Internet-of-Things, data integrity is key. Data from sensors and other devices along the production and logistics chain needs to be compatible and secured to derive business value and avoid harm. While most chemical industries have made progress in protecting their server landscapes from cyber breaches, the field and bus-level data are often transmitted without authentication and encryption. Considering the growing number of wireless connected devices, there is a need for a suitable, standardized, and scalable solution. Furthermore, the increasing number of vendors that provide hardware as a service create the need for data to flow directly from the plant to the vendors (*Stable data*).

One way to ensure a safe and untampered data flow could be using blockchain technology that is built on authentication, encryption, and immutability of data (*Fraud*).

7. Corruption free tendering processes: logistics, operation, maintenance

When building new or debottlenecking chemical plants, tendering processes are often used to find the best and cheapest manufacturer. Similar processes are used for purchasing software and other services. Blockchain technology can be used to reduce corruption by digitizing the process in the following manner: Instead of bids, interested parties only submit a digital fingerprint (hash) of their offers using a smart contract that manages the date of receipt. Once the bidding phase is over, companies can reveal their bids and the company that issued the bidding can verify the validity of the bids (*Stable data*). This avoids that any person or intermediate company gets to see the bids before the process is completed and hence no illegal agreements can be made (*Intermediaries, Fraud*).

These seven examples are some of our expert hypotheses and research areas. It's allowed, and we encourage you, to think even bigger. Since financial impact and peculiarity are different in every company, of course, we cannot quantify the impact for you nor select by value.

Leaders can start the blockchain transformation tomorrow by engaging in four steps

Blockchain technologies are unlikely to pass the chemical industry. To not miss a huge opportunity and avoid getting disrupted technology companies, we recommend starting by engaging in the following four steps:

1) Get inspired by blockchain applications in edging areas like, e.g., energy, manufacturing, automation (e.g., meet the industry partners of successful blockchain projects)

2) Identify your own 'blockchain champions'! Allow them to think freely and build blockchain knowledge (you won't find blockchain talents on the market right now, especially not with the necessary understanding of your business)

3) Think through our “Value-driven Blockchain in Chemicals” framework and identify core value pools and new business models

4) Get your hands dirty focusing clearly on improving the business, even if it is in a sandbox (bounded environment for deployment) at first to really know what all the turmoil is about.

If you like this article, we will be happy if you forward it to your colleagues or share it on social networks.

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Narayanan, A., Bonneau, J., Felten, J., Miller, A., and Goldfeder, S. (2016). Bitcoin and Cryptocurrency Technologies: A Comprehensive Introduction. Princeton University Press, Princeton, NJ, USA.

Sikorski, J., Haughton, J., Kraft K. (2017). Blockchain technology in the chemical industry: Machine-to-machine electricity market. *Applied Energy*, 195, 234-246.

[1] In this article, the term blockchain technology is used for distributed systems, which operate on a peer-to-peer basis, where information and/or its change is cryptographically linked over time and access to the system is based on public and private key cryptography. This includes ledgers as well as other concepts as for example the tangle.

[2] https://www2.deloitte.com/insights/us/en/focus/signals-for-strategists/emergence-of-blockchain-consortia.html

[3] http://www.finextra.com/finextra-downloads/newsdocs/The%20Fintech%202%200%20Paper.PDF

[4] https://www.gartner.com/doc/3627117/forecast-blockchain-business-value-worldwide

[5] We recommend the books at the end of the article. A visual introduction into a public blockchain protocol can be found here: https://hackernoon.com/wtf-is-the-blockchain-1da89ba19348

[6] https://sampl.fks.tuhh.de/fileadmin/user_upload/projects/sampl/publications/SAMPL_Flyer_A4_Lay12_EN_WEB.PDF

[7] https://www.basf.com/en/company/news-and-media/news-releases/2017/07/p-17-277.html

[8] See https://blogs.sap.com/2017/06/12/footprints-in-the-sand-blockchain-in-the-chemicals-industry-pt-1/ and http://www.digitalistmag.com/digital-economy/2018/03/06/6-ways-blockchain-impacts-chemical-industry-05922047.

[9] https://www.linkedin.com/pulse/blockchain-technology-commercial-panacea-every-dr-phd-dr-adrian