EQUITY RESEARCH | May 24, 2016

The following is a redacted version of the original report. See inside for details.

Goldman Sachs

Is the hype around blockchain justified? Since Bitcoin introduced the world to the concept of secure distributed ledgers, much has been written about their potential to address other business problems. But the discussion often remains abstract, focusing on the opportunity to decentralize markets and disrupt middlemen. In the latest in our **Profiles in Innovation** series, we shift the focus from theory to practice, examining seven real-world applications of blockchain, such as enhancing trust in the Sharing Economy, building a distributed smart grid, lowering the cost of title insurance, and changing the face of finance across capital markets, trading and control. We identify, itemize, and quantify the players, dollars and risks for blockchain to reach its full potential.

James Schneider, Ph.D.
(917) 343-3149
james.schneider@gs.com
Goldman, Sachs & Co.

Alexander Blostein, CFA
(212) 357-9976
alexander.blostein@gs.com
Goldman, Sachs & Co.

Brian Lee, CFA
(917) 343-3110
brian.k.lee@gs.com
Goldman, Sachs & Co.

Steven Kent, CFA
(212) 902-6752
steven.kent@gs.com
Goldman, Sachs & Co.

Ingrid Groer, CFA
+61(2)9321-8563
ingrid.groer@gs.com
Goldman Sachs Australia Pty Ltd

Eric Beardsley, CFA
(917) 343-7160
eric.beardsley@gs.com
Goldman, Sachs & Co.

PROFILES IN INNOVATION

BLOCKCHAIN

Putting Theory into Practice

The Goldman Sachs Group, Inc.

Table of Contents

Payments / Fintech	Financials	Energy	Lodging / Leisure	Management
James Schneider, Ph.D.	**Alexander Blostein, CFA**	**Brian Lee, CFA**	**Steven Kent, CFA**	**Robert Boroujerdi**
james.schneider@gs.com	alexander.blostein@gs.com	Brian.K.Lee@gs.com	steven.kent@gs.com	robert.boroujerdi@gs.com
Jordan Fox	**Ingrid Groer, CFA**	**Michael Lapides**	**Lara Fourman**	
jordan.fox@gs.com	ingrid.groer@gs.com	michael.lapides@gs.com	lara.fourman@gs.com	
Pierre Safa	**Conor Fitzgerald**	**Hank Elder**		
pierre.safa@gs.com	conor.fitzgerald@gs.com	hank.elder@gs.com		
	Eric Beardsley, CFA			
	eric.beardsley@gs.com			
	Grayson Barnard, CFA			
	grayson.barnard@gs.com			

Note: The following is a redacted version of "Profiles in Innovation: Blockchain" originally published May 24, 2016 [88pgs]. All company references in this note are for illustrative purposes only and should not be interpreted as investment recommendations.

Portfolio Manager's summary

Blockchain has captured the imagination of Silicon Valley and Wall Street alike, leaving behind its origins as the underlying technology of Bitcoin. Yet much of the discussion around its potential uses remains abstract. The focus is on the power of a distributed ledger to decentralize markets and undermine the control of existing middlemen.

But the potential of blockchain is more nuanced and far-reaching than that simple narrative. To move beyond the theoretical to the practical, we explore a range of specific real-world applications across a cross section of markets and industries, including travel, energy, real estate, and finance. We illustrate where the attributes of blockchain are best suited to the business problems at hand and quantify how it might shift the dynamics of the industry.

A key takeaway across these applications is that blockchain is not just about disintermediating the middleman. In some cases, blockchain could disrupt markets and existing participants, while in others, it promises to help drive cost savings by reducing labor-intensive processes and eliminating duplicate effort. And in some instances, it can create new markets by exposing previously untapped sources of supply. The common thread is that by enabling a fundamentally new type of database technology that can be distributed across organizations, blockchain creates the foundation for solving problems or seizing opportunities that have eluded current systems.

What is blockchain?

For a detailed explanation of blockchain and how it works, see page 8.

The heart of blockchain's potential lies in the unique properties of a distributed database and how they can improve transparency, security, and efficiency. Historically, organizations used databases as central data repositories to support transaction processing and computation. Control of the database rested with its owner, who managed access and updates, limiting transparency, scalability, and the ability for outsiders to ensure records were not manipulated. A distributed database was practically impossible because of technology limitations. But advances in software, communications, and encryption now allow for a distributed database spanning organizations.

In its purest form – as used by Bitcoin to create and track units of the crypto-currency – blockchain is a shared digital ledger of transactions recorded and verified across a network of participants in a tamper-proof chain that is visible to all. Permissioned or private variations add a layer of privileging to determine who can participate in the chain – and we expect the majority of commercial applications to use some form of permissioned model.

What is blockchain good for?

We believe blockchain's transparency, security, and efficiency make it a particularly good choice for reshaping businesses that are bogged down by inefficiencies, and for enabling new business models based on distributed marketplaces and technology. Blockchain is not a "cure all" or a substitute for fixing broken business processes, but we believe it is particularly well suited to address a variety of problems:

- **Facilitating secure, de-centralized transactions among many parties in the Internet of Things:** Because of the inherently decentralized nature of the ledger, blockchain is particularly effective at handling distributed transactions among a very large number of parties. In addition, blockchain delivers a high level of security for each transaction because of the cryptographic verification and validation among parties. As new distributed economic models evolve that cover tens or even hundreds of millions of assets (such as cars or apartments in the case of the Sharing Economy) or machines (the Internet of Things),

secure, distributed transaction models will be needed to facilitate transactions. We explore this application in our Smart Grid case study.

- **Reducing fraud and increasing trust with increased security:** In many parts of the world, corruption can lead to counterfeiting or alteration of official records. For example, bribery might drive a government insider to change a record describing the amount of a payment made, or the owner of record of a particular asset. Similarly, a malicious actor might attempt to selectively alter or destroy records (for example a cyber-hacker changing payment records or trades between parties). Because each transaction is uniquely encoded via cryptography and this encoding is validated by other parties on the blockchain, any attempt to alter or remove transaction information would be detected by others and corrected by other nodes. We present a case study in which Airbnb could help accelerate the Sharing Economy with a blockchain-based reputation management solution.
- **Increasing transparency and efficiency in multi-party transactions:** In any transaction involving two or more parties, the same transaction is typically entered separately by each party into that organization's own independent systems. In the world of capital markets, the same trade order might be entered into the systems of two counterparties. In each organization, the transaction works its way through middle-office and back-office systems – at which point errors can create the need for costly reconciliation processes with significant manual intervention. By using a distributed ledger technology such as blockchain, organizations can streamline the clearing and settlement process, shorten settlement windows, and avoid substantial capital and operating expenses. We examine a number of capital markets applications where blockchain can be applied to significantly lower costs.

We summarize the potential for each use case on pages 6-7.

Putting theory into practice: Real-world applications and benefits

When we consider these applications in real-world scenarios, the dollar benefits start to become apparent. We conducted case studies of seven concrete business problems that would benefit from the full value proposition of blockchain: building "trust" between parties in the Sharing Economy (peer-to-peer (P2P) lodging); better managing supply, demand, and security on the US electrical grid; verifying a property title; clearing and settling securities trades; and complying with anti-money laundering and "know your customer" regulations.

- **Building trust between counterparties in the Sharing Economy**: P2P lodging sites like Airbnb have already begun to transform the lodging industry by making a public market in private housing. However, adoption may be limited by concerns about safety and security (guests) and property damage (hosts). By enabling a secure, tamper-proof system for managing digital credentials and reputation, we believe blockchain could help accelerate the adoption of P2P lodging and generate **$3 - $9 billion in incremental revenue opportunity through 2020.**
- **Transforming the US electricity industry by enabling distributed markets**: Today, consumers rely on power generated centrally by utilities. With the advent of rooftop solar and high-capacity battery technology, individuals can potentially act as distributed power providers. We think blockchain could be used to facilitate secure transactions of power between individuals on a distributed network who do not have an existing relationship – **a $2.5 - $7 billion annual opportunity**.
- **Reducing transaction costs in underwriting title insurance**: Homeowners buying or re-financing property are subject to significant transaction costs, including title insurance, where the title search process can be labor-intensive. Along with business process changes, blockchain could reduce title insurance premiums and **generate $2 - $4 billion**

in cost savings in the US by reducing errors and manual effort. In emerging markets, land registration systems could help reduce transaction and financing costs.

We illustrate what a blockchain-enabled, decentralized power market could look like – and how it would differ from the current utility model – on page 23.

- **Streamlining clearing and settlement of cash securities**: Despite the relatively low transaction costs for securities such as equities, up to 10% of trades are subject to various errors, leading to manual intervention and extending the time required to settle trades. By applying blockchain to the clearing and settlement of cash securities – specifically, equities, repo, and leveraged loans – we estimate the industry **could save $11 - $12 billion in fees, OpEx, and capital charges globally** by moving to a shorter, and potentially customized, settlement window. While we do not treat other cases in detail in this report, blockchain could also potentially **eliminate significant additional costs** across FX, commodities, and OTC derivatives.
- **Improving efficiency in anti-money laundering (AML) and "know your customer" (KYC) compliance**: Storing account and payment information in a blockchain could standardize the data required for an account, thereby improving data quality and reducing the number of falsely identified "suspicious" transactions. A tamper-proof record could also ease the process of getting to know a client and demonstrating compliance with AML regulations – **generating $3 - $5 billion in cost savings.**

When will blockchain really start to matter?

We expect to see early-stage technical prototypes within the next two years, with limited market adoption in 2-5 years and broader acceptance in 5-10 years. We believe consumer-focused Sharing Economy and social media companies could begin to implement blockchain-based identity and reputation management systems in relatively short order. In capital markets, we expect to see a series of early prototypes over the next two years on a limited scale and with limited numbers of participants. Broader market acceptance is likely to take as much as 10 years given the regulatory oversight required and large number of market participants in large-scale markets such as cash equities in the US.

What could go wrong?

Like all new technologies, the adoption of blockchain in the real world will involve challenges. Below we highlight some of the most significant ones:

- **Standards**: We expect many special-purpose permissioned blockchains to be created for a wide variety of applications. To gain widespread adoption, we believe technical standards will be needed to ensure similar technical implementations across industries – particularly in cases where multiple blockchains need to interoperate with each other.
- **Commercial conflicts and business process differences**: In many ways, a blockchain database is only as good as the data and business process that underlie it. Failure to reach a consensus among counterparties because of business process or commercial conflicts could significantly slow or even halt blockchain's adoption.
- **Privacy:** Applying a distributed database to commercial transactions raises the question of whether organizations want to share information about counterparties. Similarly, the idea of "reputation management" could raise concerns about the ability to permanently impact reputations. Users will need to carefully weigh these factors.
- **Speed and performance**: Any distributed database is inherently slower than a centralized one, raising the question of whether blockchain is appropriate for high-speed, high-volume applications. Although many blockchain variants promise to enhance performance, this remains a question for commercial applications.

Blockchain
Applications Abound

Blockchain's unique characteristics give it the potential not only to **streamline existing markets**, but also to **redistribute markets** and **create new ones**. Here, we summarize five examples and highlight select public and private companies that are enabling blockchain in the real world.

Creating New Markets

The Sharing Economy: Lodging

$3-9bn increase in US booking fees through 2020

What blockchain can do

Ease identity and reputation management. Blockchain can securely store and integrate users' online transaction and review history with identification and payment credentials—making it easier to establish trust between parties. This information can be used to streamline transactions and enhance review quality.

Select enablers
Airbnb, HomeAway, FlipKey, OneFineStay

Incumbents at risk
Hotel industry

Redistributing Markets with "Creative Destruction"

Smart grid

$2.5-7bn new US market for distributed power

What blockchain can do

Enable transactions in a decentralized power market. Blockchain can connect local power generators (think: neighbors with solar panels) to consumers in their area, enabling distributed, real-time power markets. A blockchain-enabled market could also increase grid security and spur adoption of smart grid technologies.

Select enablers
TransActive Grid; Grid Singularity

Incumbents at risk
Utility companies

Blockchain
Applications Abound

Streamlining Existing Markets

Real estate title insurance

$2-4bn annual US cost savings

What blockchain can do

Improve efficiency and reduce risk. By recording property records in a blockchain, title insurers would have easier access to the information they need to clear a title. The fact that the ledger is tamper-proof could help lower real estate fraud in emerging markets.

Select enablers

BitFury, Factom / Epigraph

Incumbents at risk

Title insurers

Cash securities (equities, repo, leveraged loans)

$11-12bn annual global cost savings

What blockchain can do

Cut settlement times and reconciliation costs. Using a blockchain-based system can significantly shorten trade settlement time, in some cases from days to just hours. It also helps lower capital requirements, OpEx and custody fees in the process.

Select enablers

Digital Asset Holdings, R3CEV, Chain.com, Australian Securities Exchange, itBit, Axoni, Ripple

Incumbents at risk

Custody banks and clearing houses

Additional savings could be achieved if blockchain is applied in other capital markets such as FX, OTC derivatives and commodities

Anti-money laundering compliance

$3-5bn annual global cost savings

What blockchain can do

Increase transparency and efficiency. Storing account and payment information with blockchain could improve data quality and reduce the number of falsely identified "suspicious" transactions.

Select enablers

SWIFT and others

Incumbents at risk

Specialty compliance software vendors

What is blockchain?

Blockchain is a shared database of transactions among parties designed to increase security, transparency, and efficiency.

Blockchain is fundamentally a new type of database technology that is optimized to tackle a unique set of challenges. Historically, databases have been used as central data repositories by organizations to support transaction processing and computation. However, databases are rarely shared between organizations due to a variety of technology and security concerns. **Blockchain is a shared, distributed database of transactions among parties that is designed to increase transparency, security, and efficiency.**

The anatomy of the blockchain can be described by the following process:

BLOCKCHAIN IS:

A database (with copies of the database replicated across multiple locations or nodes)

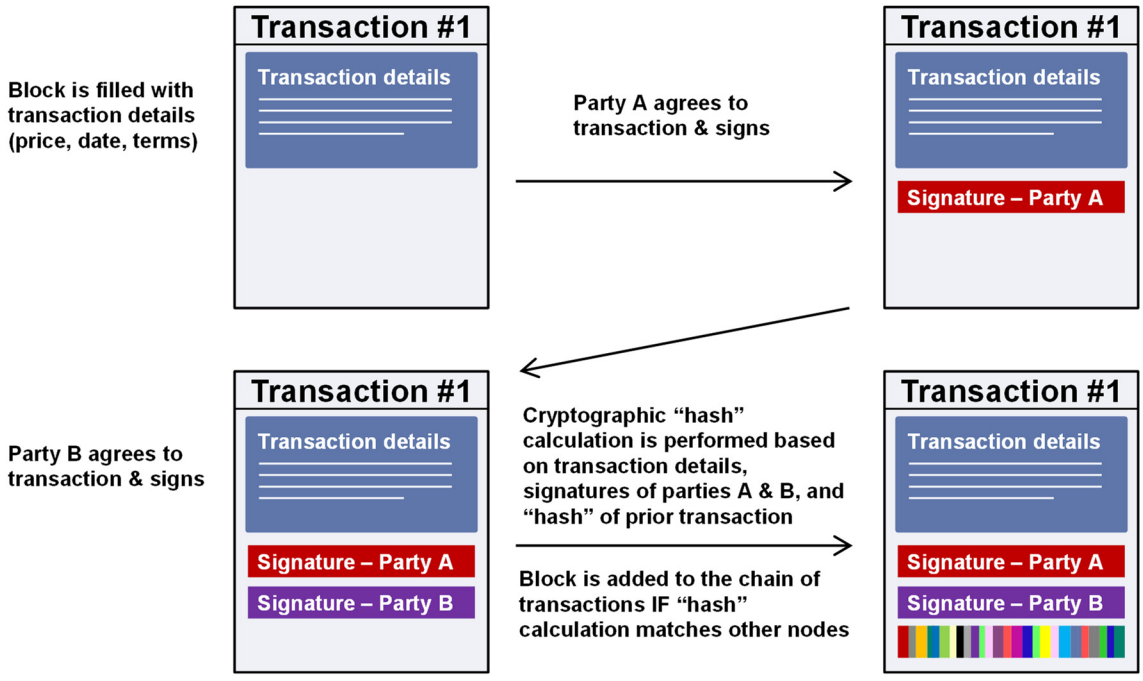
of transactions (between two or more parties)

split into blocks (with each block containing details of the transaction such as the seller, the buyer, the price, the contract terms, and other relevant details)

which are validated by the entire network via encryption by combining the common transaction details with the unique signatures of two or more parties. The transaction is valid if the result of the encoding is the same for all nodes.

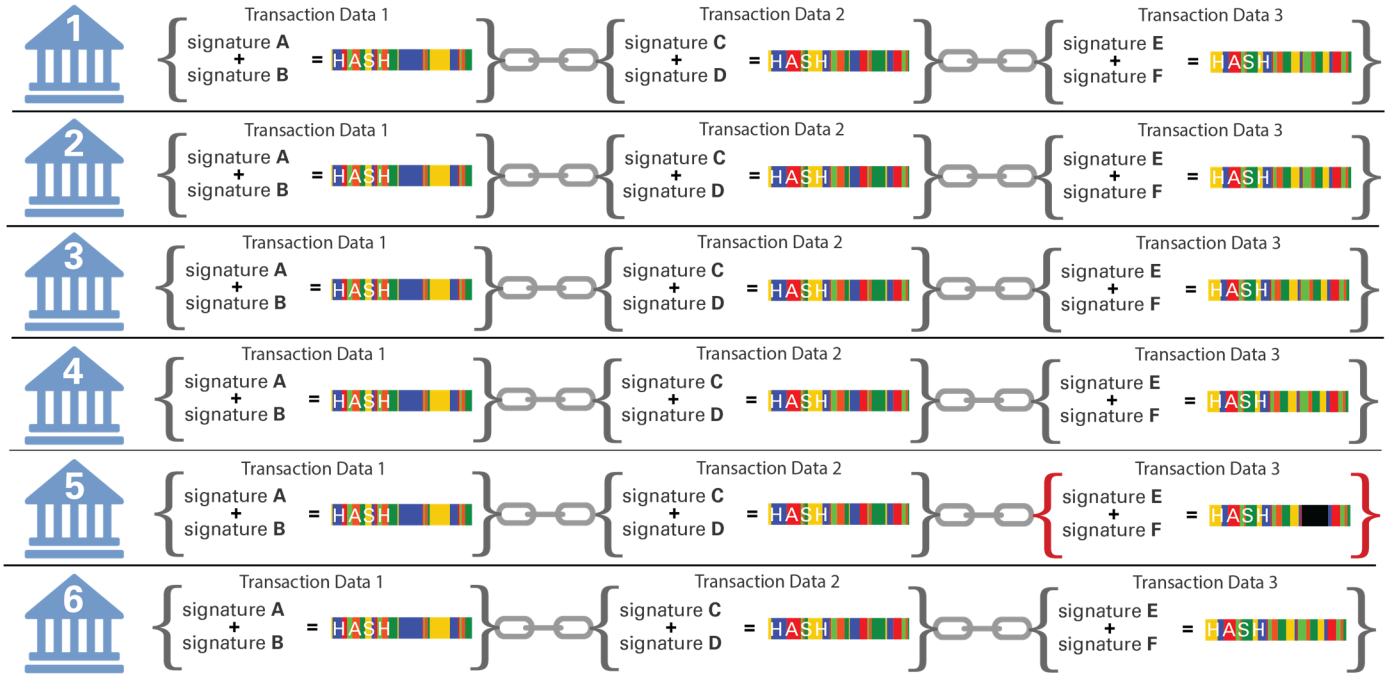
and added to the chain of prior transactions (as long as the block is validated). If the block is invalid, a "consensus" of nodes will correct the result in the non-conforming node.

Exhibit 1: Illustration of how a single block in the blockchain is built and validated



Source: Goldman Sachs Global Investment Research.

Exhibit 2: The blockchain ledger is replicated across multiple locations (we show just six here for simplicity), and each maintains its own copy, which is separately updated based on new transaction data. We show a sequence of three transactions. In the first two transactions, data and signature information are properly validated by all six nodes with matching "hash" values. However for Transaction #3 at Location #5, the hash does not match the others, and will be corrected by the others via "consensus."



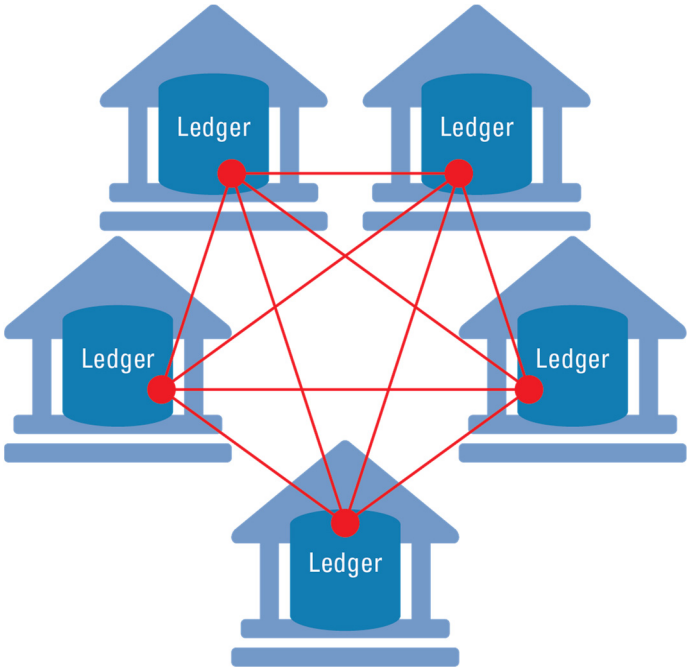
Source: Goldman Sachs Global Investment Research.

Blockchain has the following advantages over a conventional centralized database:

- **Security:** Blockchain relies on encryption to validate transactions by verifying the identities of parties involved in a transaction. This ensures that a "false" transaction cannot be added to the blockchain without the consent of the parties involved. A complex mathematical calculation known as a "hash" is performed each time a transaction is added to the blockchain, which depends on the transaction data, the identities of the parties involved in the transaction, and the result of previous transactions. The fact that the current state of the blockchain depends on previous transactions ensures that a malicious actor cannot alter past transactions. This is because if previous transaction data is changed, it will impact the current value of the hash and not match other copies of the ledger.
- **Transparency:** By its very nature, blockchain is a distributed database that is maintained and synchronized among multiple nodes – for example, by multiple counterparties who transact with each other frequently. In addition, transaction data must be consistent between parties in order to be added to the blockchain in the first place. This means that by design, multiple parties can access the same data (in some cases locally within their organizations) – thus significantly increasing the level of transparency relative to conventional systems that might depend on multiple "siloed" databases behind firewalls that are not visible outside a single organization.
- **Efficiency:** Conceptually, maintaining multiple copies of a database with blockchain would not appear to be more efficient than a single, centralized database. But in most real-world examples (including several of the case studies we examine in capital markets), multiple parties already maintain duplicate databases containing information

about the same transactions. And in many cases, the data pertaining to the same transaction is in conflict – resulting in the need for costly, time-consuming reconciliation procedures between organizations. Employing a distributed database system like blockchain across organizations can substantially reduce the need for manual reconciliation, thus driving considerable savings across organizations. In addition, in some cases (see our discussion of AML) blockchain offers the potential for organizations to develop common or "mutual" capabilities that eliminate the need for duplication of the same effort among multiple organizations.

Exhibit 3: The blockchain ledger is distributed across multiple locations, each of which is connected via a data link. This illustration shows a "permissioned" blockchain composed of a fixed number of trusted counterparties.



Source: Goldman Sachs Global Investment Research.

Blockchain: Public or private?

We expect private or "permissioned" blockchains to dominate most commercial applications. The distributed ledger used for Bitcoin is a public ledger that can be read from or written to by anyone who wishes to transact, making it an ideal vehicle for public transactions between individuals who don't know each other. In fact, the public nature of the Bitcoin ledger is one of the most appealing and novel features of the distributed database. Yet for many high-volume commercial transactions (for example, in securities transactions between counterparties or sharing information between commercial partners in a supply chain), trust is already established among the participants – and in many cases they desire transaction privacy. Private or "permissioned" blockchains behave in the same way as the public blockchain, except that the identity of anyone who attempts to access the blockchain must be validated against a list of pre-validated market IDs. We believe that the vast majority of commercial blockchain applications – particularly in capital markets – are likely to use private or permissioned blockchains.

BLOCKCHAIN opportunities in numbers

A SMARTER GRID

9%

The amount of power lost in transfer between centralized power plants and end consumers. Blockchain could connect local producers and consumers in a decentralized real-time energy marketplace, reducing the amount of long-distance transfer required and vulnerabilities inherent in a centralized supply model.

MOVING MARKETS

The proportion of the total cost base that blockchain could cut out of US cash equities. We see similar cost-cutting opportunities across global capital markets.

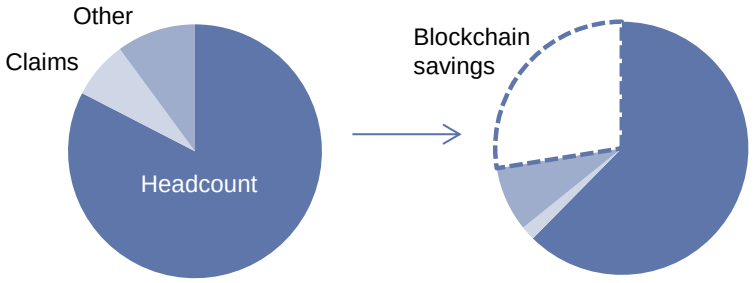
16%

TRUST BUT VERIFY

30%

The share of US property titles that are found "defective" at the time of a real estate transaction and thus require a labor-intensive clearing process. Blockchain could simplify verification and reduce the associated actuarial risk—which would reduce customer premiums by around 30%.

Title insurers' operating costs: Potential for $3bn in savings



ROOM SERVICE

500mn

The number of room nights we expect P2P lodging to add to global industry supply by 2020. Blockchain could accelerate this growth by providing secure identity and reputation management.

FALSE POSITIVE

99.9%

The percentage of "suspicious" financial transactions that end up being false positives upon manual review. The primary cause is poor data quality—which a tamper-proof, distributed ledger could improve.

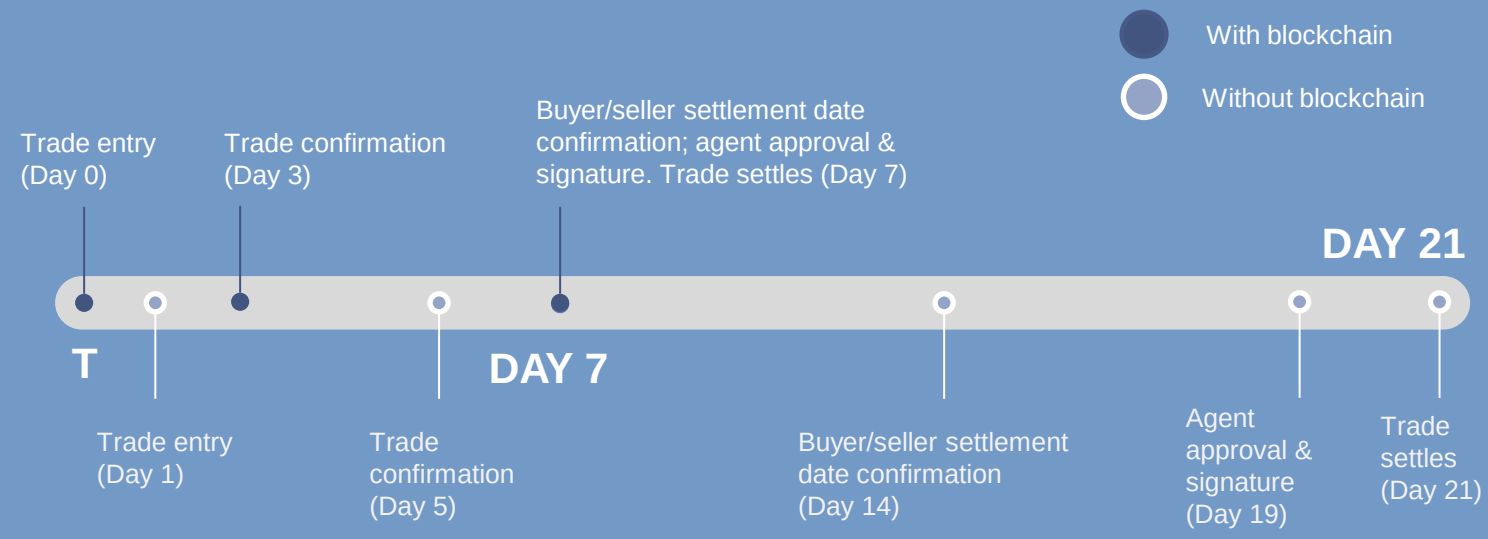
NET SAVINGS

$50bn

The amount of capital savings in repo markets from centralized clearing and netting, partly enabled by blockchain.

LET'S SETTLE THIS

Milestones in leveraged loan settlement with and without blockchain



Putting Blockchain to Work: Seven Case Studies

Case Study 1: Accelerating the Sharing Economy with reputation management

We believe blockchain has the potential to help accelerate the adoption of the Sharing Economy by enabling identity and "reputation management" systems, allowing users to "credentialize" themselves by validating their identity and past behavior. The Sharing Economy has already begun to unleash industry disruption by opening up significant amounts of previously untapped private capacity – in cars with Uber and in housing with Airbnb. However, user authentication and reputation is particularly challenging for lodging. With a secure, tamper-proof system based on blockchain, users can more easily credentialize themselves, which could increase ease of use and security for guests and hosts alike, driving accelerated adoption.

What is the opportunity?

The Sharing Economy is predicated upon maximizing asset utilization by monitoring availability and adjusting for demand in real time. Relative to other asset classes such as cars, lodging is both longer lived (involving stays of multiple days or even weeks) and more personal (tied to sleeping and living conditions, and the maintenance of an owner's personal property), so the decision-making process is more complex for both hosts and guests. The higher the trust level between host and guest, the greater the willingness of guests to rent (faster adoption rate) and the greater the willingness of hosts to rent to individuals (greater asset utilization). **By securely credentializing both guest and host information and ensuring the accuracy of reputation information, blockchain can be used to streamline user experience and increase safety and trust in P2P lodging.**

Ultimately, we see potential for a "social blockchain" database that aggregates social credentials and authenticates previous transactions, effectively helping users carry their "social and trust credentials" across merchant platforms.

What are the pain points?

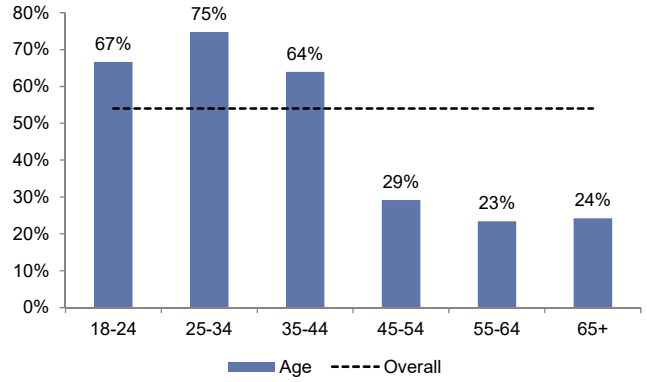
Although P2P lodging is already on a steep growth trajectory – in terms of both market awareness and adoption – we see an opportunity for blockchain to **increase the safety, quality, and effectiveness of the transaction process. Reputation management and safety concerns remain significant challenges to the adoption of P2P lodging, and are areas where we see potential for blockchain to help.**

- **Significant time for host to respond to guest requests:** Once a guest has selected a property she would like to book, she will usually engage in a messaging conversation with the host – during which the host may ask a series of questions about the guest's background. Depending on the host's speed of response, 24 hours or more may elapse before the guest receives an initial response. Moreover, messaging conversations may extend over significant periods of time. We believe these conversations could be shortened if the host and guest could quickly assess reputation.
- **Difficulties in assessing suitability and quality of host, guest, and property:** Reputation is a challenge for both guest and host. A guest may not be able to determine the quality of the host's offering based solely on reviews or pictures, and could potentially benefit from knowing the host's reputation on other marketplaces or previous transactions. We would point out that review fraud and tampering (both false positive and negative reviews) are problems faced by nearly all online marketplaces. Blockchain offers a traceable and tamper-free historical record of interactions.

Hosts may lose occupancy and revenue in situations where there is uncertainty about a guest's reputation, preferring to turn down the booking rather than risk damage to their personal property. While people in the highest income brackets are more likely to be familiar with P2P lodging sites, they are also less likely to use these services. We believe that by using blockchain to enforce additional security and allow more transparency, P2P lodging sites could potentially attract more upmarket users.

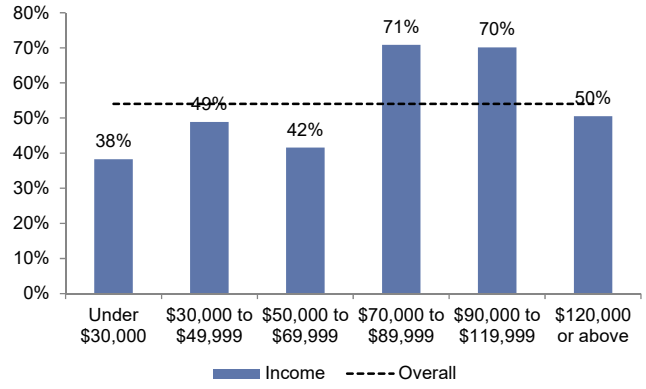
- **Payment surety and speed**: When people make a reservation today, they are required to pay for the entire cost of their stay – and typically enter their credit information again with each new booking. In Airbnb's case, it then releases the funds to the host 24 hours after the guest checks in. We believe blockchain could help accelerate the payment to the host, both by securely storing payment credentials and by streamlining requirements that could automatically trigger payment as defined in a smart contract.

Exhibit 4: Younger travelers are more likely to use P2P lodging sites among people familiar with them
% of respondents who used P2P lodging sites in the last year (overall = 54%), 4Q15



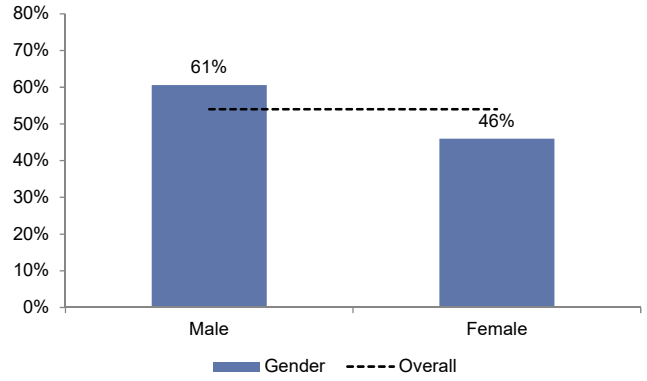
Source: Survey of 2,000 US consumers – Goldman Sachs Global Investment Research. Note: The sample was limited to people familiar with P2P lodging sites who traveled at least one day in the last year.

Exhibit 5: Travelers in the highest income bracket are less likely to use P2P lodging sites among people familiar with them
% of respondents who used P2P lodging sites in the last year (overall = 54%), 4Q15



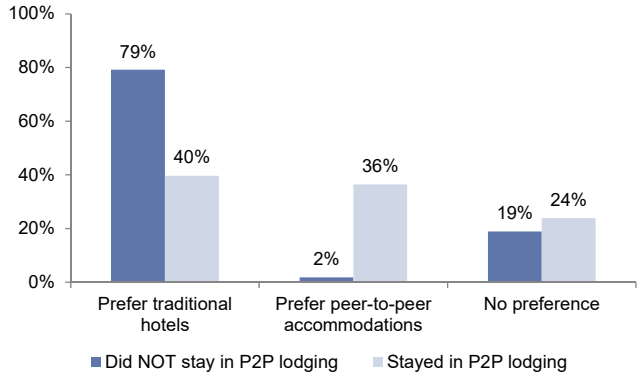
Source: Survey of 2,000 US consumers – Goldman Sachs Global Investment Research. Note: The sample was limited to people familiar with P2P lodging sites who traveled at least one day in the last year.

Exhibit 6: : Males are more likely to use P2P lodging sites than females
% of respondents who used P2P lodging sites in the last year (overall = 54%), 4Q15



Source: Survey of 2,000 US consumers – Goldman Sachs Global Investment Research. Note: The sample was limited to people familiar with P2P lodging sites who traveled at least one day in the last year.

Exhibit 7: If people have used a P2P accommodation, the likelihood that they prefer traditional hotels is halved
Question: When factoring in everything from price to location to quality, do you prefer P2P accommodations or traditional hotels?



Source: Survey of 2,000 US consumers – Goldman Sachs Global Investment Research. Respondents limited to people familiar with these accommodations; "stayed in P2P accommodation" cohort has stayed in one in last five years, 4Q15

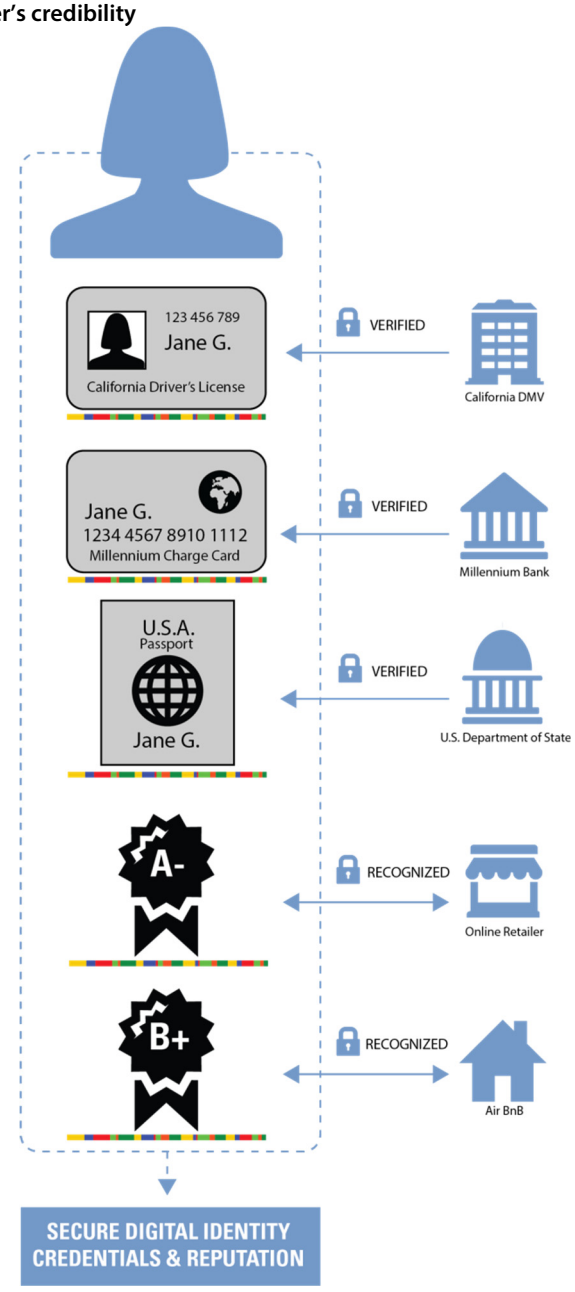
What is the current way of doing business?

P2P lodging sites (Airbnb, HomeAway, FlipKey, OneFineStay, etc.) are online marketplaces that allow people to list, find, and rent apartments and whole-home accommodations. As an example, Airbnb's site offers over 2 million listings across 191 countries and has accommodated 60 million guests. The platform has already been highly successful in streamlining lodging rental through a relatively straightforward process. Among other services, P2P lodging sites verify listings, maintain a messaging system so hosts and guests can communicate, and manage a platform used to collect and transfer payments.

1. **Booking:** After signing in with their login, guests are able to browse different lodging options based on the city selected. The website features pictures of housing availability, including pricing, neighborhood details, and reviews from previous guests. When making a booking, the guest and the host may engage in messaging, which can significantly prolong the booking process.
2. **Transaction processing:** When guests make a reservation, they are required to provide a deposit for the entire cost of their stay. Airbnb's policy is to release the funds to the hosts 24 hours after the guest checks in.
3. **Reviews:** Under Airbnb's current framework, hosts and guests may leave 500- word reviews, and the history of such reviews is available to all users.

Ensuring quality and safety for both host and guest: Users of P2P lodging sites currently rely on three tools to determine the quality of their transacting counterparty and ensure personal safety: (1) manual or automatic validation of ID information; (2) user profile and reviews; (3) messaging prior to booking. While these tools, used collectively, can help achieve high quality and safety standards, we believe the platform could benefit from higher integration with other social platforms and the ability to keep track of past transactions across marketplaces. **We see blockchain as ultimately enabling a registry of social and commercial interactions, helping users carry their credentials across different marketplaces.**

Exhibit 8: Blockchain offers the potential for a user to securely tie identity and payment credentials to a unique identifier, along with digital reputation information (from verified reviewers), which can help augment the user's credibility



Source: Goldman Sachs Global Investment Research.

Airbnb completed the acquisition of the startup ChangeCoin, a blockchain technology company, in April 2016. In a March 2016 interview with *City AM*, Airbnb CTO Nathan Blecharczyk commented that Airbnb is considering using blockchain in managing reputation information, stating that "within the context of Airbnb, your reputation is everything, and I can see it being even more so in the future," and that "we're looking for all different kinds of signals to tell us whether someone is reputable, and I could certainly see some of these more novel types of signals being plugged into our engine." Recognizing the difficulty of accurately determining the impact of P2P lodging on the hotel industry, we present a sensitivity analysis to show how even modest changes in P2P

lodging adoption (using Airbnb as an example) could have a meaningful impact on the hotel industry.

We think blockchain could help enhance P2P lodging in the following ways:

Booking

- **Security: Enhancing "Verified ID" with Blockchain:** To help build trust in the Airbnb community, the company has created a process called "Verified ID." Verified ID connects a person's Airbnb profile with other key information about the individual. The process entails (1) uploading a copy of a government-issued ID, (2) connecting another social media profile to the Airbnb account (Facebook, Google, LinkedIn), and (3) uploading an Airbnb profile photo with contact details (phone/email). Airbnb reports that Verified ID continues to gain steady adoption. **We believe blockchain could help accelerate and increase the security of the Verified ID process by securely storing a user's ID, payment information (privately), reputation information, past transactions, and reviews – thereby streamlining the booking process.**
- **Increasing trust in the booking process:** According to Airbnb (see our lodging team's March 9, 2016, report, *Takeaways from meeting with Airbnb CFO, Laurence Tosi*), about 40% of rentals booked are rooms in a house or apartment, as opposed to the entire residence – which highlights the importance of ensuring safety for both guest and host. Although validating identification and credentials helps authenticate a user, it does not address a user's past history. Blockchain enables both guests and hosts to integrate their past history of transactions securely, ensuring that all reviews are authenticated by counterparties with their unique digital signatures.

Payment

- **Securing payment credentials and automating the release of funds upon contract satisfaction:** In many instances, users must re-enter their credit card information for each new transaction. Even in cases where users maintain their credit card on file, we believe blockchain has the ability to increase payment security by tying payment to stored ID information. In addition, when guests make a reservation they are required to make a deposit for the entire cost of their stay, which is released to the host 24 hours after check-in. **Blockchain could be used to automate the release of payment via a "smart contract" when predefined conditions are satisfied.**

Reviews

- **Elevating the review system with blockchain-based authentication:** One of the most vexing commercial problems in social media is user reviews. In many cases (such as restaurants and retail), online customer reviews are commonly falsified. In some cases, a business owner may create multiple consumer IDs in order to post positive reviews, or may solicit help from friends who have not in fact engaged in a business relationship. In other cases, competitors attempt to influence consumers' buying behavior by posting negative reviews of rivals. Blockchain could allow for a tamper-free review ecosystem. Specifically, the review would not be accepted unless digitally signed by the actual reviewer and accompanied by authentication of the reviewer's stay (and payment).

Who could be disrupted?

We believe blockchain could potentially have a meaningful impact on the adoption of P2P lodging, driven by the following points:

- **P2P has significantly expanded supply in an already oversupplied industry:** Under our assumptions, Airbnb alone represented 1.5% of total US room demand at the end of 2015, which could expand to 6.5% in 2020. Under our first blockchain scenario (200bps faster supply growth), Airbnb would reach 7.9% share of total US room demand in 2020, while our 600bps scenario yields 11.3% share, highlighting the high sensitivity of Airbnb's share to relatively small changes in supply growth estimates.
- **Established players are likely to face market share erosion:** Under our current estimates, Airbnb's current offering already makes it a sizable competitor of the industry's most established players. With the company's estimated 52k US occupied room equivalents in 2015, under our 200bps/400bps/600bps blockchain scenarios, Airbnb has the potential to reach 320k/391k/473k occupied room equivalents by 2020 vs 260k in our base case.
- **Analyzing the RevPAR impact:** As Airbnb offerings tend to be at a lower price point, we assume each Airbnb room booked translates into one less hotel room booked. Applying this to our scenarios shows ~200-400bps of negative RevPAR impact in 2020.

Exhibit 9: Worldwide booking revenue would reach $102bn in 2020 under 600bps case vs $56bn in base case
Airbnb Worldwide and US Booking Revenue (US$ mn) – 2015-2020

Worldwide booking revenue (US$ mn)	2015	2016	2017	2018	2019	2020	Cumulative	Delta vs Base	% Delta
Base Case Scenario	7,522	12,822	20,272	29,963	41,818	55,779	168,175	0	0%
Blockchain - 200bps faster growth	7,522	12,977	21,052	32,416	47,913	68,844	190,723	22,548	13%
Blockchain - 400bps faster growth	7,522	13,132	21,844	34,986	54,595	84,067	216,146	47,971	29%
Blockchain - 600bps faster growth	7,522	13,287	22,649	37,676	61,896	101,685	244,714	76,539	46%
US booking revenue (US$ mn)	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**Cumulative**	**Delta vs Base**	**% Delta**
Base Case Scenario	1,788	2,920	4,413	6,223	8,267	10,470	34,081	0	0%
Blockchain - 200bps faster growth	1,788	2,955	4,583	6,733	9,472	12,922	38,453	4,372	13%
Blockchain - 400bps faster growth	1,788	2,990	4,755	7,267	10,793	15,779	43,373	9,292	27%
Blockchain - 600bps faster growth	1,788	3,025	4,931	7,825	12,237	19,086	48,892	14,811	43%

Source: Goldman Sachs Global Investment Research.

Challenges to adoption

Privacy concerns: We believe one of the greatest obstacles to the adoption of blockchain in this context is the perception of a loss of consumer privacy. In effect, a blockchain-based system would aggregate the user's **ID, payment information, reputation, past transaction history, and reviews.** We would point out that this is already commonly done across a broad range of e-commerce platforms (Amazon, Expedia, airline websites) in a far less secure way (simple password control). However, we believe users could have concerns about a distributed database that stores their sensitive personal and financial information. **Ultimately, we believe the strong level of underlying security with a blockchain-based solution would minimize these objections over time.**

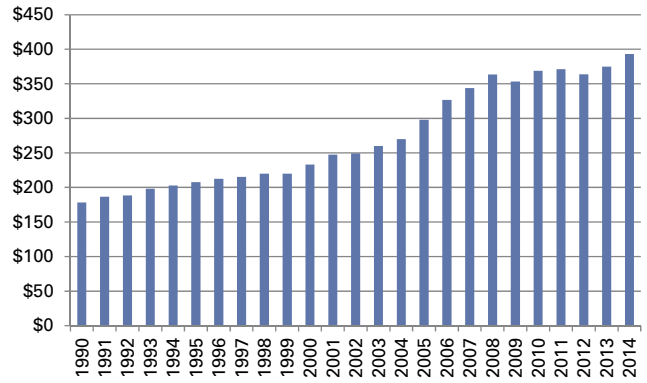
Case Study 2: Building a distributed Smart Grid with blockchain

Over the coming decades, we expect the electrical grid to transform from a centralized utility-based model to one with an increasing number of decentralized resources, real-time pricing signals, and the ability to more closely match power supply and demand. A core piece of this transformation will involve the modernization of the grid via smart meters, smart appliances, renewable generation, and energy storage – the combination of which we expect will create millions, if not billions, of decentralized nodes across the grid that are capable not only of receiving and transmitting data, but also of entering into peer-to-peer transactions. We foresee the opportunity for blockchain to play an important role in facilitating communications, transactions, and security between millions of transacting parties. In our view, blockchain will enable a decentralized energy marketplace that could significantly shift the balance of spending toward investments in distributed energy resources, while also creating a potential redistribution of $2.5-$7bn of electricity revenue to new market participants (i.e., not utilities).

What is the opportunity?

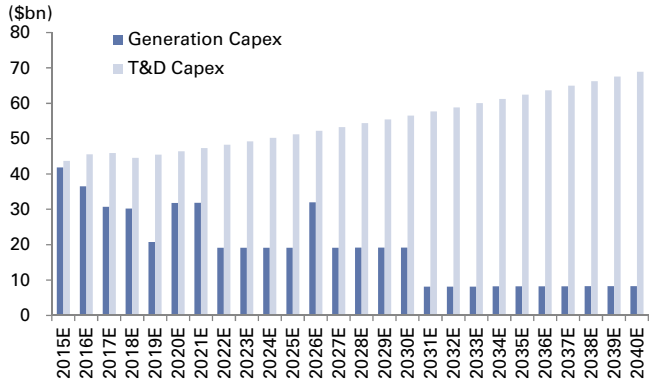
Utilities monopolize the US electricity market. Over $360bn of electricity revenue is generated in the US annually by the traditional utility model – a model that has dominated the power markets over the past century and is based on large local/regional utility monopolies. Structurally, the economies of scale of large power plants have driven investment in centralized resources (e.g., coal/gas plants) that are located far away from population centers, with power then being shipped across miles and miles of transmission and distribution infrastructure to the end consumer. In fact, while overall demand growth has declined to ~1% annually owing to energy efficiency and the general economic backdrop in recent years, US utilities have continued to ramp capital spending, with a greater mix of capex now shifting to transmission and distribution infrastructure. As a result, electricity rates have continued to rise despite deflationary pressures in key commodity inputs into the power markets, namely natural gas. We believe the modernization of the grid – driven by smart meters/devices, renewables, and storage – is already beginning to disrupt the traditional utility model, particularly as customers seek to engage directly in power purchase decisions via self-generation and/or energy arbitrage through storage solutions. **Blockchain could further the disruptive potential of these new resources on the grid, eventually creating an increasingly decentralized grid where energy users are also energy generators, transacting directly with each other in the electricity market.**

Exhibit 10: The US electricity market is large and continues to grow
Annual electricity sales in US ($ bn), 1990-2014



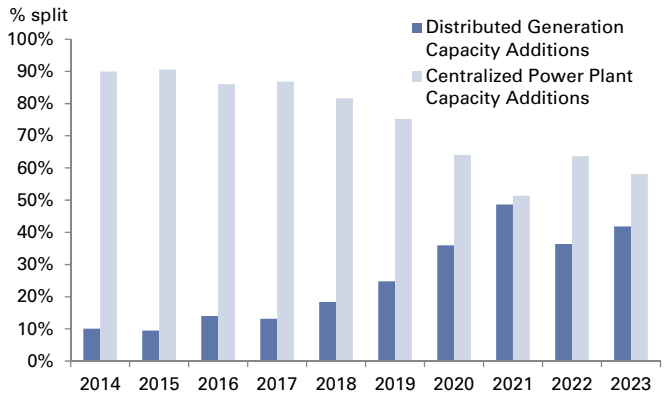
Source: EIA.

Exhibit 11: We expect transmission and distribution capex to increasingly outstrip spending on generation
Mix of US utilities capital expenditures, 2015E-2040E



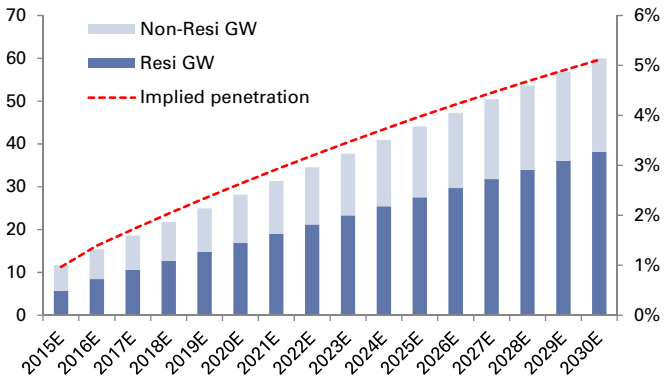
Source: EEI, Goldman Sachs Global Investment Research.

Exhibit 12: The shift toward distributed generation is occurring…
% of centralized generation capacity adds vs. distributed, 2014-2023E



Source: EIA.

Exhibit 13: …as rooftop solar gains increasing penetration in both residential and non-residential markets
Rooftop solar penetration in US, 2015E-2030E



Source: Goldman Sachs Global Investment Research.

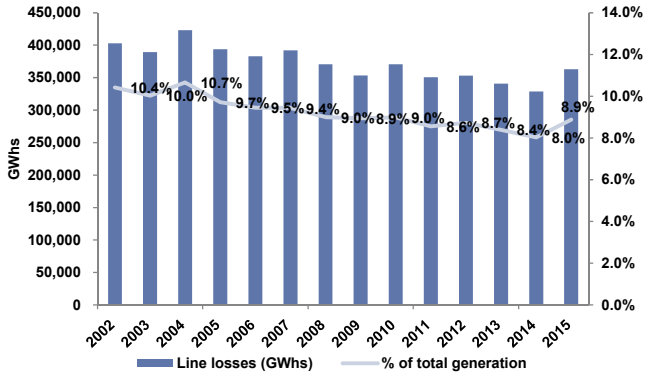
What are the pain points?

Line losses. Pushing power across miles of wires creates inefficiencies as voltages are stepped up and down, resulting in lost power. We estimate that 8%-9% of total generation actually never reaches the final end user – resulting in billions of lost dollars in potential revenue.

Reliability. According to a Congressional Research Service study, outages result in $25-$70bn of annual costs. The centralized infrastructure of the power grid leads to broad swaths of the population losing power at once, a phenomenon that appears to be increasing according to data from the EIA.

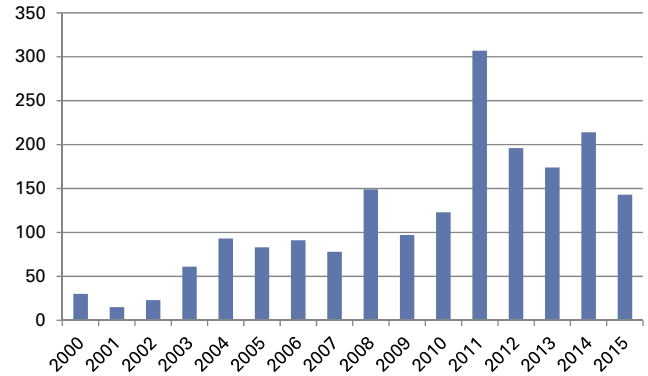
Load balancing. Grid operators use a number of options to balance short-term supply and demand fluctuations for power, including demand response programs. In many cases, these programs are optional and require consumers to play a significant role by responding to financial incentives (e.g., lower rates).

Exhibit 14: Line losses have averaged close to 10% historically and 8%-9% in recent years
Line losses as % of total US generation



Source: EIA, Goldman Sachs Global Investment Research.

Exhibit 15: Outages have been on the rise over the past decade-plus, as the grid has continued to age
Electric disturbance events, 2000-2015



Source: DOE.

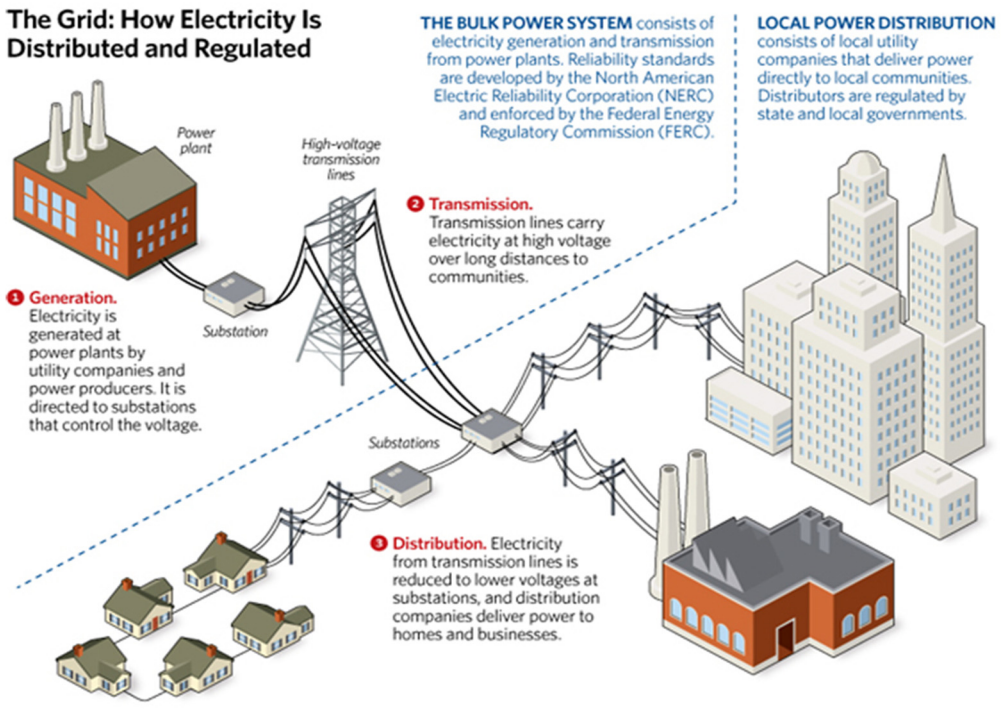
What is the current way of doing business?

The electric power grid pairs centralized production with distributed consumption. Since the advent of alternating current (AC) transformers in the late 1800's, the electrical grid has been dominated by centralized power generation and long-distance transmission infrastructure. Some key features of the electrical grid and power markets in the US include:

- Over 3,000 utilities exist across the US
- 5,800 major power plants supply electricity to the grid
- Over 450,000 miles of high voltage transmission lines deliver power to homes and businesses

Distributed resources, particularly rooftop solar, effectively sell excess power back to the grid under net metering. For energy producers that are not utilities – predominantly rooftop solar customers – the form of remuneration for power sent back to the grid is subject to net metering. This is a billing mechanism, used in more than 40 states, that credits customers for electricity provided to the grid from approved renewable energy generation systems. Under net metering, credits are generated at the prevailing retail utility grid rate in most cases and enable consumers to lower their traditional electricity bill; however, no direct revenue is generated. Net metering has faced significant utility pushback in a number of states where rooftop solar has gained traction (e.g., Hawaii, Arizona, Nevada). We believe that pressures to lower the rate at which net metered power is credited will continue to increase over time.

Exhibit 16: Current electricity grid



Source: The Heritage Foundation. Note: FERC regulation does not apply to Texas.

How does blockchain help?

Business impact: Blockchain could help create a decentralized energy marketplace. In what would be the most disruptive scenario for the electricity market, we believe the combination of blockchain and communications technology could facilitate secure transactions and payment between millions of parties, enabling a decentralized energy marketplace. Simply put, the distributed nature of blockchain could allow distributed energy users to sell power seamlessly to consumers in their vicinity in a literal localization of energy production and consumption. The potential appears real.

Realistically, this potential exists in small and localized microgrids – residential and industrial – given that the vast majority of power generation will likely remain centralized for decades to come. We also note that significant regulatory changes would be required for blockchain to have a major disruptive impact on the traditional utility business model. On the other hand, the potential for traction could be higher in off-grid opportunities.

Exhibit 17: A blockchain-based microgrid in Brooklyn, NY, is enabling residents to generate power and sell directly to neighbors

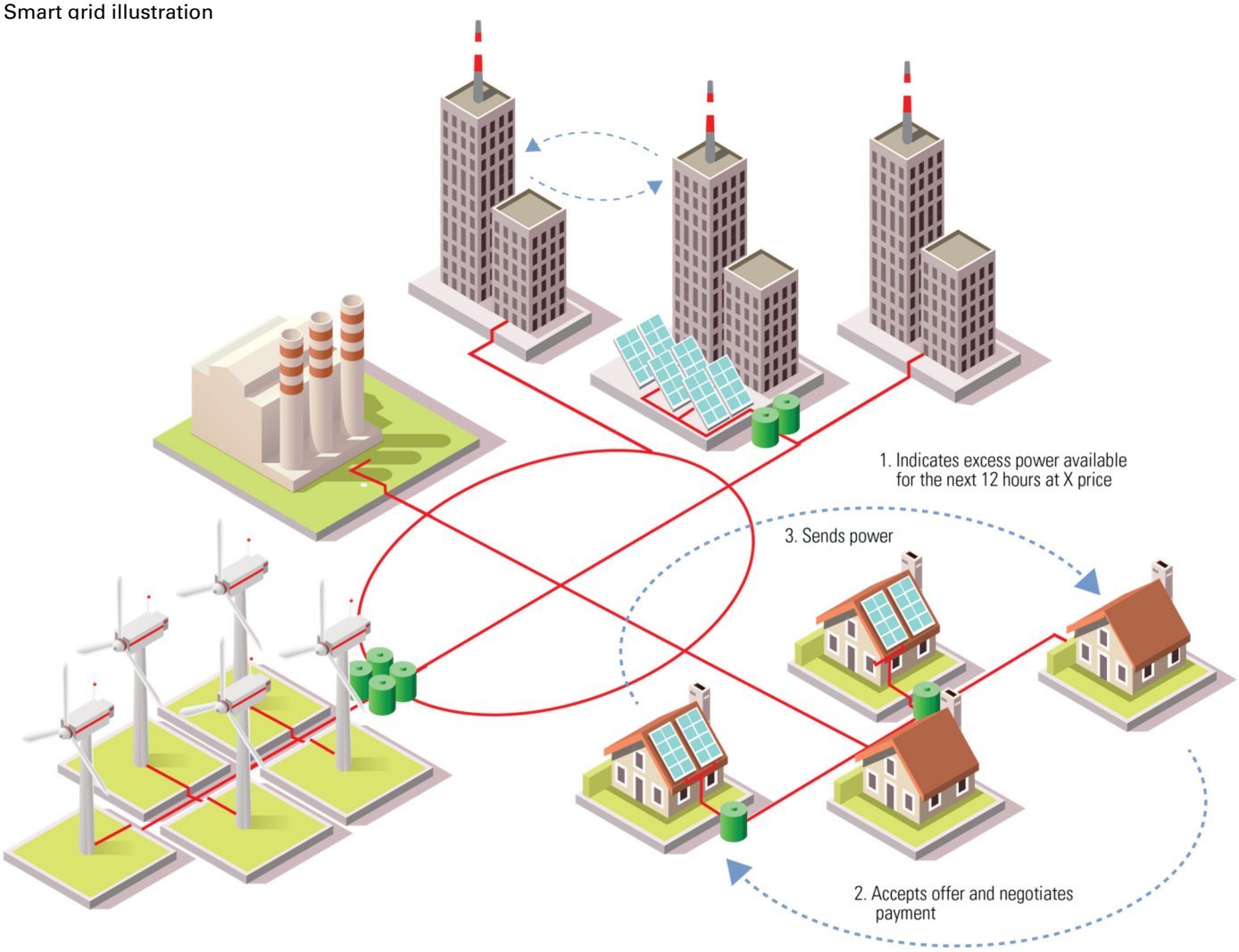
Source: TransActive Grid.

Structural impact: Blockchain drives more distributed grid infrastructure. The ability to transact in the energy markets as a localized generator would likely drive a bigger shift toward technologies that enable a distributed grid. These would include smart grid networks and devices, but also Internet of Things (IoT) appliances and electric vehicles, as well as power resources like rooftop solar, energy storage, and even fuel cells. Theoretically, the more distributed the grid becomes, the more reliable and efficient it could be in matching power supply and demand – sending real-time pricing signals and reducing expenditures on costly transmission and distribution infrastructure, among other factors.

Policy impact: Blockchain could end the need for net metering. We believe the adoption rate of distributed solar has largely benefited from policies such as net metering, which support the economics of going solar vs. paying for grid power in an increasing number of states

across the US. However, the longer-term outlook for net metering is not certain owing to growing opposition from utilities. We believe distributed energy producers would embrace an alternative to selling back to the grid – e.g., selling into a localized merchant market, for which blockchain could provide the distributed and secure transactional backbone to enable a decentralized marketplace.

Exhibit 18: The distributed Smart Grid enabled by blockchain could allow distributed power generators and consumer to interact with each other
Smart grid illustration



Source: Goldman Sachs Global Investment Research.

Combining blockchain with the Internet of Things could enable the negotiation of distributed power transactions. By using distributed wireless or wireline data links in a mesh network (or another more traditional communications architecture), distributed producers could automatically broadcast information on excess power availability along with relevant duration information. In principle, consumers could automatically respond with their power needs. Using a blockchain-based ledger, machine proxies of producers and consumers can negotiate pricing and enter into a power sale transaction. We believe the Smart Grid use case may offer a good example of when a public blockchain could be used to enable secure transactions between users who do not know each other. We can imagine multiple "Smart Grid blockchains" being enabled on a local or regional basis.

Quantifying the opportunity

We estimate that blockchain could open up a decentralized marketplace for distributed energy sales that would reach $2.5-$7bn.

- **Total capacity.** By 2030, we forecast rooftop solar penetration will approach 5% in the US, up from roughly 1% today. This would imply the presence of at least 60GW of total distributed generating capacity on the grid by that time.
- **Mix of import vs. export.** We believe a significant portion of this power will be consumed at the residential or business site where it is being produced. While SolarCity estimates that an average residential customer consumes 60%-80% of their solar power (with the rest being net metered back to the grid), we believe the ability to participate directly in energy sales could result in larger systems being built over time – and thus the availability of more energy for export. For purposes of our analysis, we assume 50% is consumed locally and 50% is sold into the market.
- **Pricing.** Currently, the average retail price of electricity is roughly $0.10 per kWh (including both residential and commercial). We assume prices will increase at a 2%-3% annual rate, in line with recent historical trends. Also, it is noteworthy that under net metering, most states still require utilities to credit the full retail electricity rate for excess power that is sent back to the grid. Based on this, we see three different potential pricing scenarios existing in a market where distributed energy generators are also able to sell power to other users.

    1. **Avoided cost:** By being located on site, distributed energy resources do not require transmission and distribution investment. Thus, the avoided cost by building a distributed power source vs. a centralized power plant is broadly equal to the cost of generation, which we estimate to be one third of the cost of retail electricity (though this varies by utility). Notably, this is the level utilities are largely arguing for in ongoing net metering debates in terms of the rate at which solar power users should be compensated for the excess power they send back to the grid. **Assuming all distributed energy generators sell at avoided cost, we estimate a $2.5bn opportunity.**
    2. **10% discount to retail:** Assuming net metering rates do approach avoided cost, distributed energy producers will have less and less of an incentive to sell back to the grid because of the low rates. This would drive either more self-consumption or a shift to sell power to a customer besides the utility (e.g., other users), if given the opportunity. We assume other energy users would buy from outside the utility if they received a discount, and we model a 10% savings in the high-end case of our analysis. **Assuming all distributed energy generators sell at a 10% discount to the grid, we estimate a $6.9bn opportunity.**
    3. **Mid-point. Assuming all distributed energy generators sell at a price between avoided cost and a 10% discount to the grid price, we estimate a $5.1bn opportunity.**

Exhibit 19: We estimate blockchain could enable roughly $2.5-$7bn of revenue potential for distributed energy generators in a decentralized marketplace for electricity
Revenue sensitivity in a decentralized energy marketplace

Pricing assumptions			
Current avg retail price of electricity	$	0.10	per kWh
Average annual increase		2.5%	
Implied 2030 avg retail price	$	0.14	per kWh
Generation as % of price		33%	
Implied avoided cost	$	0.05	per kWh

Generation assumptions		
Distributed solar penetration	5%	
Installed capacity by 2030	60	GW
Capacity factor	20%	
Total distributed generation	105,120	GWh
% of power consumed at site	50%	

	Low	Mid	High
	Avoided cost	Mid-point	10% discount
Implied price per kWh	*$ 0.05*	*$ 0.10*	*$ 0.13*
Total revenue potential ($bn)	$ 2.5	$ 5.1	$ 6.9

Source: Goldman Sachs Global Investment Research.

Who could be disrupted?

In our view, the utility industry could potentially be disrupted by blockchain, while we think producers of distributed energy resources (e.g., rooftop solar) and smart devices/meters are likely to see higher volume potential. The more that energy generation and consumption shifts to a decentralized transaction that does not involve a utility (outside of providing the wires that transmit energy), the more traditional utilities could see their volumetric revenue potential continue to decline. While much of this potential is longer term and would require significant regulatory changes, we note that the shift to a more distributed grid is already taking place: Rooftop solar is now roughly 1% of the electricity capacity on the US grid. We think more and more consumers could eventually decide to produce their own power on site if they have the ability in the future to generate revenue from that production.

Challenges to adoption

- **Regulatory:** Many states have laws that prohibit sales of electricity by non-utility entities. For blockchain to enable distributed energy users to transact directly in energy sales, regulation will need to evolve.
- **Technical:** Smart grid infrastructure is deployed across roughly half of the US grid today and would be required for devices and meters to transact via blockchain.
- **Physical limitations:** Blockchain enables secure transaction processing, but power will still need to be physically delivered from one node to another on the grid, which will still need to be maintained by utilities/transmission operators.
- **Costs:** Proponents of centralized power generation argue that the economies of scale of large power plants result in lower costs relative to distributed energy resources. Although that is true today, future cost reductions in distributed energy appear likely

given the technology roadmaps of areas such as solar and battery storage. In addition, a reduction in required transmission and distribution investment is favorable for all-in cost considerations in the shift from centralized to distributed generation.

- **User behavior:** While blockchain would theoretically make transactions seamless and automatic, energy consumers have traditionally not been energy generators – and they have definitely not been revenue generators. This would require a dramatic change in customer thinking about the application of energy usage/consumption in a more widely distributed grid environment where market dynamics between buyers and suppliers are not transparent.
- **Security:** Blockchain would drive the potential for millions of transactions on the grid. This would imply higher risk given the sheer number of points on the grid that are involved; however, blockchain's enhanced security and ability to register participants could potentially strengthen grid security.

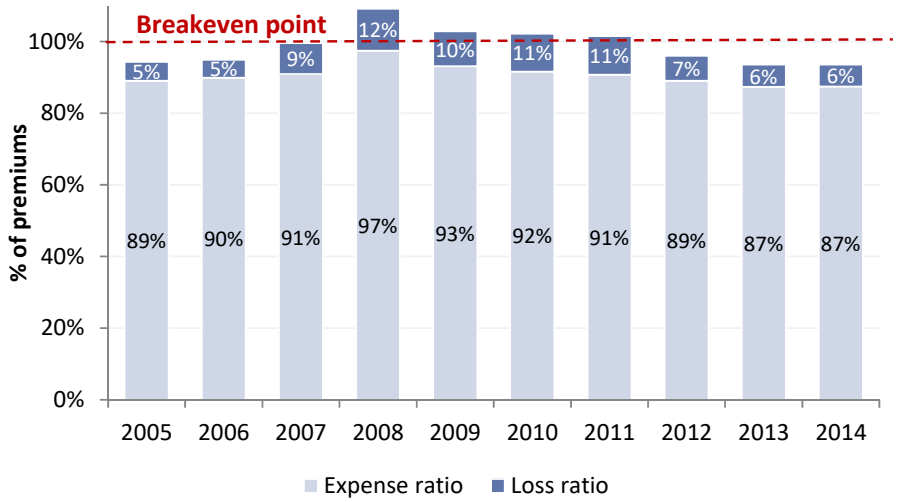
Case Study 3: Reducing transaction costs in real estate title insurance

We see opportunity for blockchain to reshape the title insurance industry. By registering real estate on a distributed ledger, blockchain could streamline the manually intensive practice of examining public records when validating titles in real estate transactions. We estimate blockchain could drive $2 - $4 bn in US industry cost savings due to reductions in headcount and actuarial risk.

What is the opportunity?

Title insurance is a niche but sizeable market in the US, with $11bn in premiums paid in 2014. Title insurance exists mainly to protect a property owner and/or mortgage lender's financial interest in a real estate transaction (residential or commercial) against loss from title defects. Title defects include, but are not limited to, outstanding liens, easements, or other encumbrances unaccounted for at the time of the transaction. Importantly, title insurance premiums, as compared with other insurance lines, are largely determined by the insurer's underwriting cost factors as opposed to actuarial risk of expected losses. This is because title insurers conduct a search of public records prior to insuring the title, expending significant resources upfront in order to augment loss prevention. In this way, premiums are subsequently set to cover associated operating expenses, plus a profit margin (2%-5%). While this business model serves to limit claim losses (5%-7% of premiums), title companies must absorb relatively high fixed cost structures, which raise premium rates. **We believe blockchain could meaningfully lower transactional risk associated with the existing property registration system in the US, introducing significant cost efficiencies that would benefit the end consumer.**

Exhibit 20: Title insurers absorb substantial costs in conducting property title searches in order to augment loss prevention, supporting profit margins of 2%-5% on average
Title insurance industry combined ratio, 2005-2014



Source: A.M. Best Information Services.

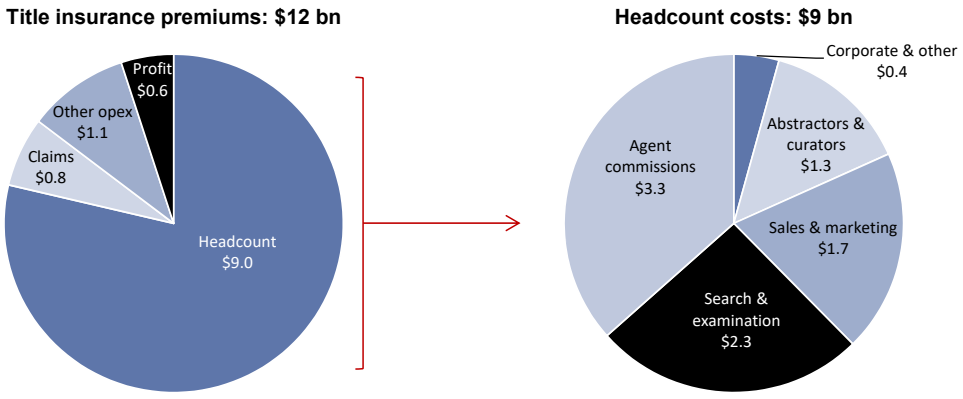
What are the pain points?

Property title search is labor-intensive and costly. Today, the US property registration system is organized as a "chain of title," with historical transfers of property title being manually recorded on an ongoing paper trail that is stored in local jurisdictions. We believe the existing system introduces three problems that directly underscore both the need for and the cost of title insurance:

- **Decentralization of property records.** Given the fact that property records are stored at the county level, title companies must build and maintain title plants – a time-consuming and labor-intensive process – in order to index the public records geographically, with the aim of increasing search efficiency and reducing claims.
- **Fallibility of paper-based recording.** We highlight that ~30% of property titles are found defective at the time of a real estate transaction, according to the American Land Title Association. We believe this is partly a consequence of manual, paper-based recording (as well as decentralization), wherein deeds, mortgages, leases, easements, court orders, and encumbrances associated with a property are recorded in a "chain of title," exposing the integrity of the record system to human error.
- **Elevated property transaction costs:** Due to the significant costs associated with property title searches as a result of the above factors, title insurance premiums primarily reflect the elevated underwriting expense and distribution cost rather than actuarial risk. Premiums run between $1,000 and $1,800 on average (representing 0.4%-0.6% of the home value assuming a $275,000 property). Residential and commercial property owners pay title premiums whether they are purchasing or refinancing a property, with residential purchase premiums roughly twice as high as refi premiums.

As a result of these factors, title insurers employ many people to examine and "cure" the property title before underwriting an insurance policy against it. Between abstractors, curators, search and examination personnel, and lawyers, as well as sales and marketing professionals, **we estimate that headcount costs represent nearly 75% of industry premiums** (Exhibit 30). We believe this relatively high fixed cost structure directly results in higher premiums for the end consumer.

Exhibit 21: Title insurers' operating cost structure largely consists of headcount costs
Illustrative breakdown of title insurance cost structure (bn)



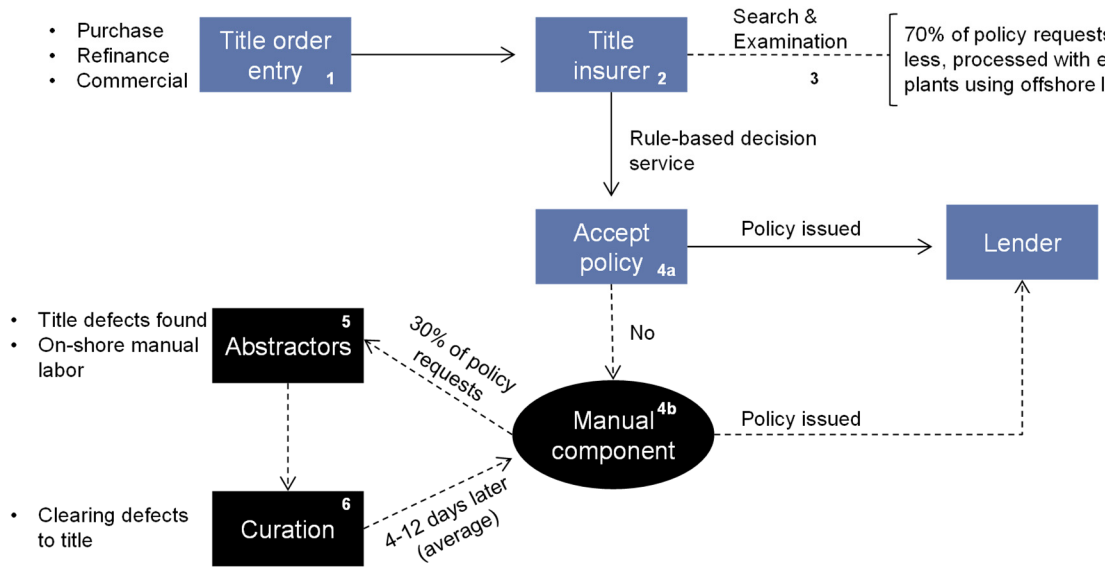
Source: Fidelity National Financial, American Land Title Association, Goldman Sachs Global Investment Research.

What is the current way of doing business?

Title insurers rely on a network of parties to underwrite every policy. In a real estate transaction (residential or commercial) that is financed with a mortgage, the property owner is required by the financing institution to obtain title insurance, which involves the following steps:

- The property owner submits a title order entry to a title insurance company.
- The title insurer then conducts an automated search and examination process using an electronic title plant. About 70% of policy requests are found to be without defect, and thus are given straight-through processing.
- However, ~30% of policy requests are found to have title defects of some type. In these instances, title companies rely on onshore labor to manually review (abstractors) and clear (curators) title issues. This process typically takes 4 - 12 days.
- Once the title is determined to be clear of outstanding liens or encumbrances, the title company will issue a policy against the security of the title.
- The property buyer pays the insurer a one-time fee for the policy at closing, which typically ranges between $1,000 and $1,800 (0.4%-0.6% of home value assuming a $275,000 property).

Exhibit 22: Title search is a manually intensive process, as abstractors and curators must process and clear paper-based property records – 30% of which are found defective at the time of the proposed transaction (sale/refinancing)
Title search process



Source: Goldman Sachs Global Investment Research.

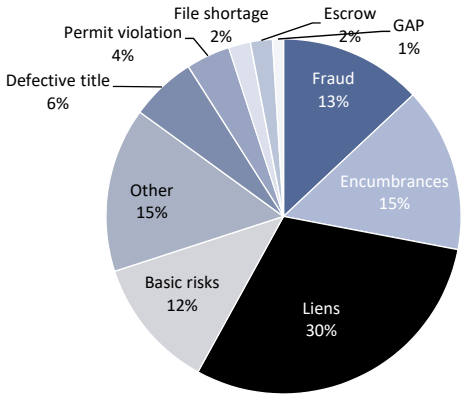
How does blockchain help?

Blockchain has the potential to eliminate transactional risk from the existing land registration system. If property records were stored on a blockchain, wherein information germane to establishing clear title was readily accessible and trusted among all parties, transfer of property title would become more efficient and secure. In particular, we believe blockchain

could supplant local real estate records as the primary conduit of property title information, helping to resolve the following pain points in today's system:

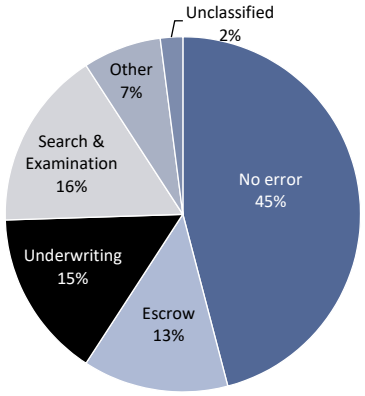
- **Property records validated by consensus help eliminate paper-based errors.** Blockchain could make paper-based property records obsolete, as all present and past real estate transactions would be meticulously stored on an immutable and decentralized ledger. Importantly, no disagreement as to the ledger's integrity would arise because the network relies on consensus. We believe this would significantly reduce title fraud risk as well as reduce the possibility of human error being introduced into the "chain of title" over time. Still, we recognize that entering and reconciling property data into any blockchain will require human intervention.
- **A shared database of real estate transactions could make property title searches more transparent and more efficient.** By aggregating localized public records in a commonly accessible format, blockchain could reduce the need for title insurers to build and maintain electronic title plants that are meant to index public real estate records, which is a time-consuming and labor-intensive process.

Exhibit 23: Sources of title claims could be easily identified with blockchain…
Claim causes



Source: First American Financial.

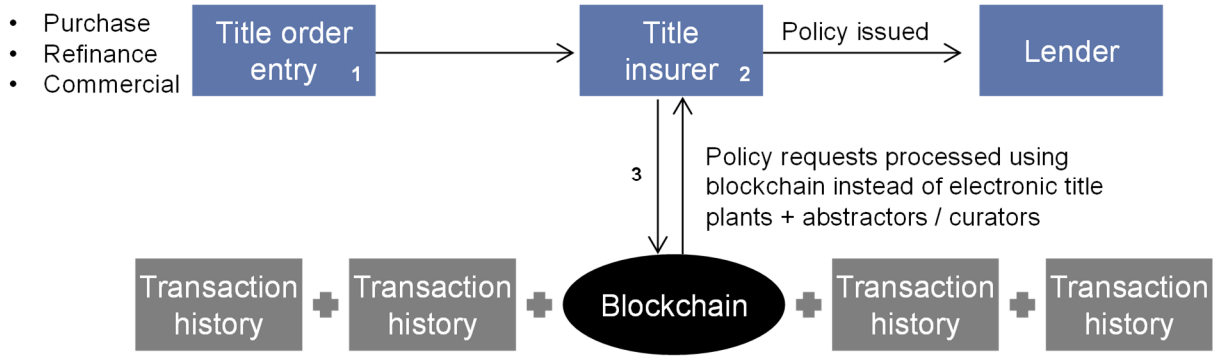
Exhibit 24: …while many process causes of claims could also be avoided with blockchain
Process causes



Source: First American Financial.

By eliminating these problems, blockchain could fundamentally disrupt the way title searches are currently conducted. As a result of greater data integrity and accessibility, we believe substantially less manual labor would be needed to examine and "cure" property title records. Thus, we would expect blockchain to introduce significant cost savings in terms of a reduction in search and examination personnel, curators, and abstractors. We would also expect blockchain to help improve actuarial risk, as property title information could become readily verifiable, reducing claim losses for title companies. **Ultimately, we believe these cost efficiencies, if realized, would be passed through to the end consumer given the fact that title insurance premiums are meant to cover underwriting expenses (plus a small margin). Blockchain could help meaningfully reduce those underwriting expenses.**

Exhibit 25: Blockchain could fundamentally disrupt the way title search is currently conducted
Blockchain title search process

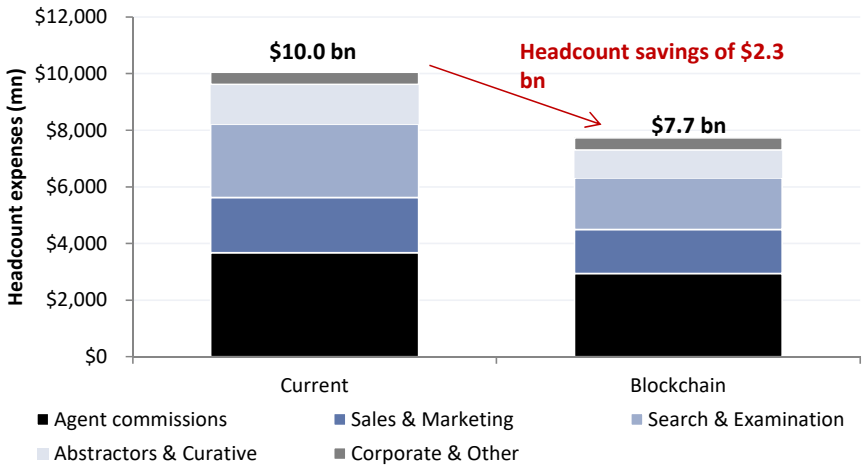


Source: Goldman Sachs Global Investment Research.

Quantifying the opportunity

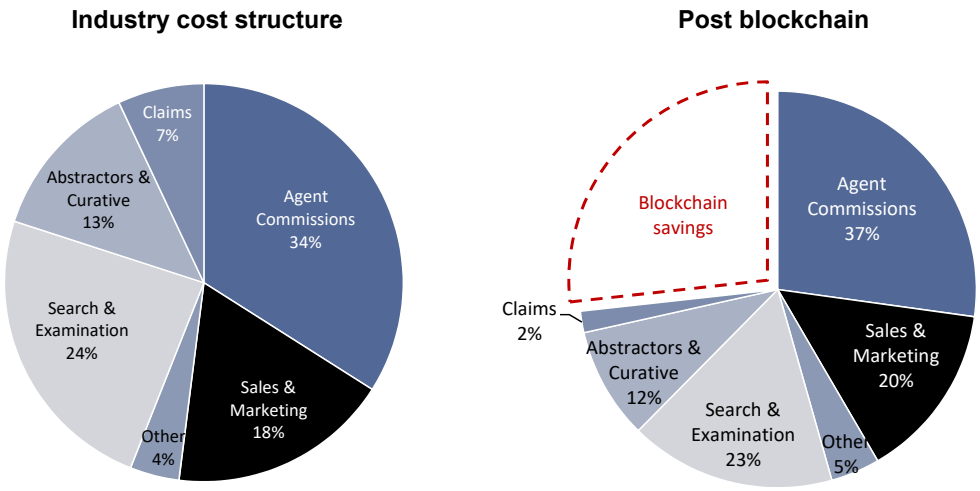
We estimate that blockchain could drive cost savings of approximately $2 - $4bn as a result of reductions in headcount and actuarial risk. We believe blockchain could streamline the manually intensive process of property title search, introducing significant headcount cost savings into the system. **In our base case, we estimate that blockchain could drive $2.3bn in headcount savings,** primarily driven by a 30% reduction in fixed headcount personnel in search & examination as well as abstract and curative functions, combined with a 20% reduction in variable expenses from agent commissions and sales & marketing (Exhibit 35 and 36).

Exhibit 26: Blockchain could drive $2.3bn in headcount savings in our base case
Estimated industry headcount operating expenses currently vs post-blockchain ($bn)



Source: Goldman Sachs Global Investment Research.

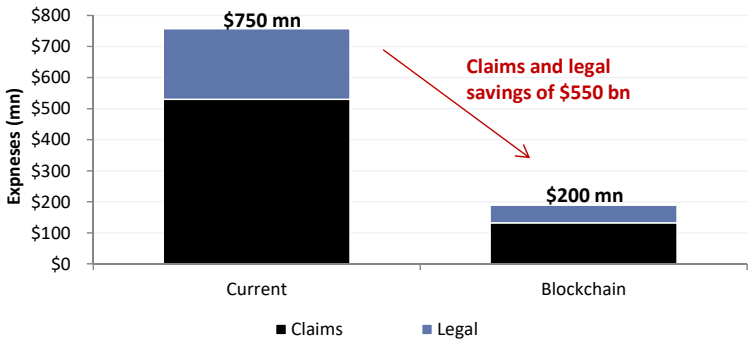
Exhibit 27: Labor-intensive underwriting expenses could decline significantly as a percentage of premiums
Estimated industry operating expense composition (as % of premiums) currently vs post-blockchain



Source: Goldman Sachs Global Investment Research.

Blockchain could also reduce the number of insurance claims as actuarial risk is improved. We highlight that roughly 5%-7% of insurance premiums are provisioned as expenses for claims to indemnify property owners and/or lenders, as well as to cover associated legal dispute fees (which represent nearly 30% of total loss provisions). While real estate transactional risk would probably not be fully eliminated if property records were linked to blockchain, we believe actuarial risk would improve significantly owing to the introduction of greater historical transparency and immutability into the property registrations system. **As such, in our base case we estimate that claim losses could decline 75%, generating annual cost savings of $550mn.**

Exhibit 28: We estimate blockchain could drive $550mn in claims/legal savings annually
Estimated insurance claims/legal expenses currently vs post-blockchain

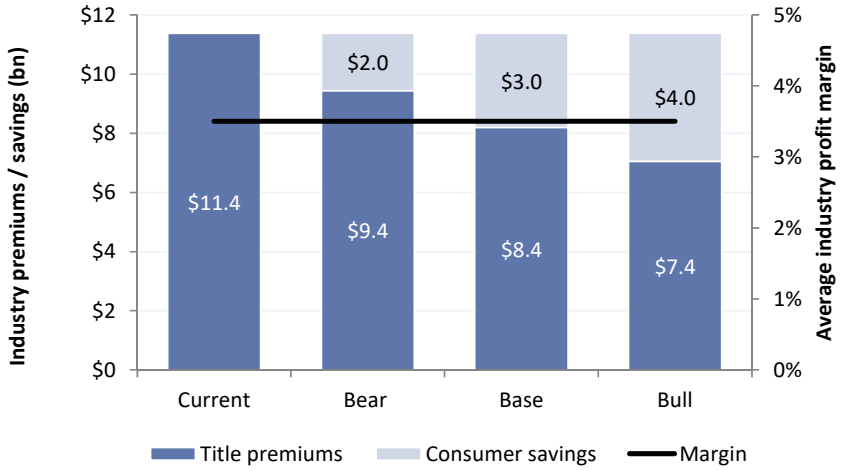


Source: Goldman Sachs Global Investment Research.

With significant cost savings from both headcount reduction and claim losses, we expect insurance premiums to proportionally decline. Recall that the cost of title insurance is traditionally set to cover the insurer's underwriting expenses. Given our assumption that blockchain could introduce nearly $3.0bn in cost savings (headcount + claim losses) into the industry cost structure – and assuming that title insurers would maintain a modest profit margin (2%-5%) – we expect premiums to decline significantly as a result. **In our base case, we expect the average premium per policy to fall to $864 (0.3% of property value) from**

an average of $1,200 currently (0.5% of property value), representing a ~30% decline. Assuming that the number of underwritten policies remains relatively stable, we believe the title insurance market could potentially shrink from $11.4bn today to $8.4bn as a result of blockchain efficiencies (Exhibit 38).

Exhibit 29: Blockchain could drive significant cost efficiencies, with savings being passed through to the consumer while title insurers maintain profit margins (2%-5%)
Sensitivity scenario: Title premiums vs. consumer savings ($bn)



Source: Goldman Sachs Global Investment Research, American Land Title Association.

As a point of reference, we highlight that our insurance premium estimates are consistent with title guarantee rates in Iowa. Iowa is the only state where the title insurance industry is a state-sponsored monopoly, designed with the intention of lowering premium rates for consumers. Iowa title guarantees run between $600 and $800 per transaction, well below industry levels. Importantly, Iowa loss rates are the lowest in any state, as less than 2% of premiums are paid to settle claims. **We believe Iowa has been able to substantially reduce premium rates and actuarial risk as a result of the following factors:**

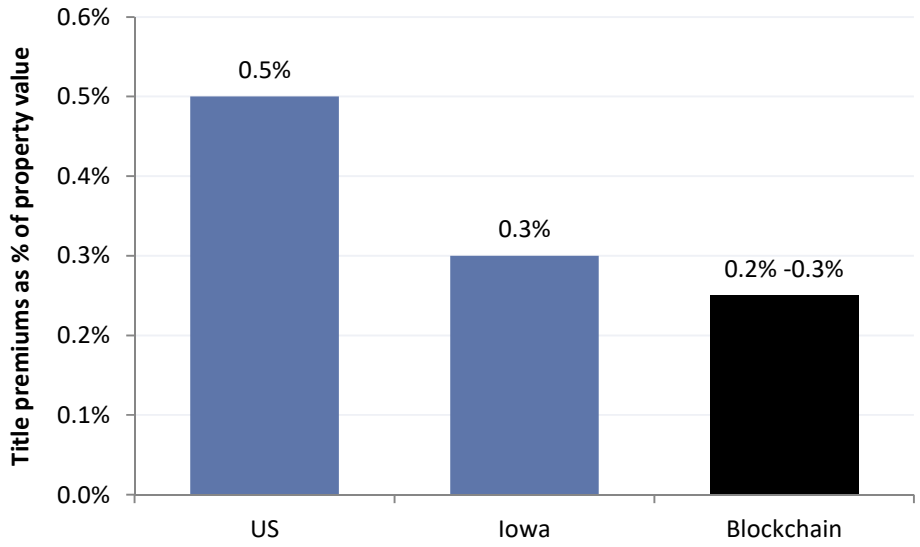
- **Efficient property records system.** Iowa uses a highly standardized system for documenting property records, and it maintains a shared online database where county records can be easily accessed from anywhere in the state. In addition, Iowa has historically put in place a stringent mortgage recording process, which has introduced greater historical transparency and data integrity into the "chain of title." As a result of these efficiencies, property title search is less time and labor intensive in Iowa relative to other states.

- **Optimized cost structure.** As a state-sponsored monopoly, the Iowa Finance Authority is able to optimize its cost structure by removing the need for marketing and referral costs from the market. Given this structural cost advantage, Iowa's government can sustainably price premiums at relatively lower rates while still supporting the overall cost structure. All profits from the system are distributed to low-income housing projects in the state.

Iowa's system is a secure and cost-efficient alternative relative to traditional title insurance. We believe Iowa's model – which benefits from more efficient property records system and an optimized cost structure – provides support for the economization of industry premium

rates in the US. We think blockchain could introduce similar efficiencies into the system, and ultimately lower the cost of insurance to the end consumer.

Exhibit 30: Blockchain could help drive lower title insurance premiums in the US
Average premiums as a percentage of purchase price (assuming $275,000 property value)



Source: Iowa Finance Authority, Goldman Sachs Global Investment Research.

Exhibit 31: In our base scenario, blockchain could drive nearly $3.0bn in total cost savings ($2.0-$4.0bn estimated range)
Cost savings by operating expense line item ($bn)

	Current		Blockchain		
Operating Expenses	Absolute cost (bn)	% of Opex	Absolute cost (bn)	% of Opex	Savings (bn)
Agent Commissions	$3.7	34%	$2.9	37%	**$0.8**
Search & Examination	$2.6	24%	$1.8	23%	**$0.8**
Sales & Marketing	$1.9	18%	$1.6	21%	**$0.3**
Abstractors, Curative & Legal	$1.4	13%	$0.9	12%	**$0.5**
Claim Losses	$0.8	7%	$0.2	3%	**$0.6**
Corporate & Other	$0.4	4%	$0.4	5%	**$0.0**
Total	**$10.8**		**$7.8**		**$3.0**

Source: Goldman Sachs Global Investment Research.

Who could be disrupted?

Title insurance companies could be impacted by blockchain. As noted above, we think blockchain could generate meaningful operating efficiencies, and allow title insurers to realize significant cost savings in conducting title searches. However, we would expect these savings to be passed through to the end consumer in the form of lower policy premiums. While commercialization of blockchain remains a longer-term phenomenon, we think it is reasonable for title companies to react in advance of this trend, potentially spurring greater automation and cost-saving efforts over the medium term.

Challenges to adoption

Fragmentation in the real estate industry. Real estate is a highly fragmented industry, so the way title insurance is conducted varies meaningfully by locality. In particular, premium pricing, regulation, and the involvement of title lawyers and agents can differ significantly between states. We believe the lack of uniformity among various title insurance parties could impede the adoption of an industry-wide blockchain standard.

Mortgage lenders' market participation. Mortgage lenders traditionally require title insurance when they provide real estate financing (residential or commercial) in order to protect themselves against potential loss from title defects. Whether or not mortgage lenders (a highly fragmented industry) would be receptive to the use of blockchain in carrying out property title searches is unclear, and they could potentially push back owing to unfamiliarity with the technology.

Infrastructure development. A blockchain-based infrastructure that operates in conjunction with existing title industry standards is needed for commercial adoption. Developing this infrastructure would require considerable investment, in our view.

What is the opportunity internationally?

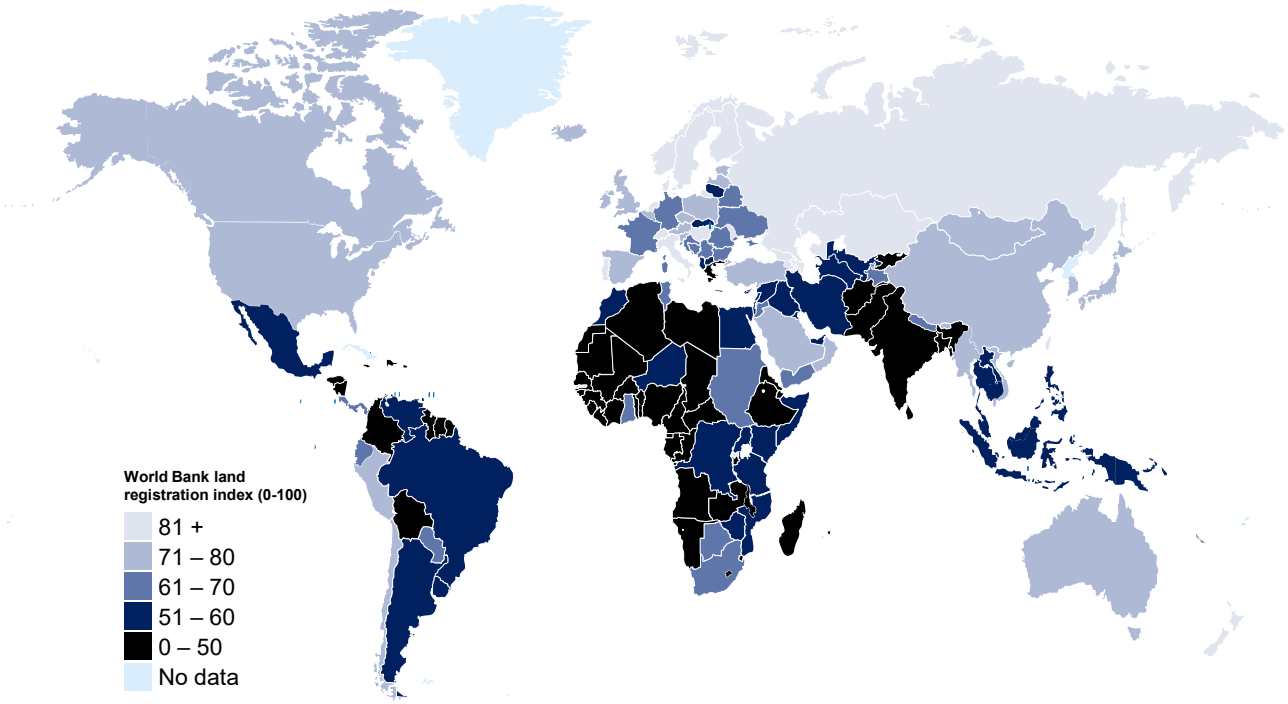
While title insurance is not common outside of the US and Commonwealth nations, we see opportunity for blockchain to transform international real estate systems by improving land registration rates. We note that real estate markets internationally, particularly in emerging markets, face meaningful inefficiencies as a result of low rates of land registration. By aggregating property records on a distributed leger, we believe blockchain could improve land registration, thus helping to resolve the following issues:

- **Real estate corruption.** Blockchain has enormous potential to improve land registration rates and, as a result, land security, potentially leading to a decline in cases of property rights abuse. The lack of formal land registration has contributed to high rates of real estate corruption in many developing nations, leading some of them to search for solutions. For example, Georgia and Honduras have expressed interest in contracting technology startups, including BitFury and Factom, to design and implement blockchain infrastructure in an effort to solve this problem.
- **Costly property transfer fees.** Property transfer fees are very high in countries with low land registration rates. In Brazil, for example, property owners typically pay up to 4% of the property value in transfer fees alone, split between notary (1.25%), registration (0.75%), and legal fees (2.00%). When this is added to real estate broker fees (3%-6%) and transfer taxes (2%-4%), total transaction costs rise to 9%-14%.
- **Prohibitive mortgage financing.** Cost-efficient sources of debt capital are comparatively limited in countries where land registration is low. We believe this is the result of a lack of asset collateral, and we highlight that the relative spread between secured and unsecured credit rates is widest in countries where land registration is low. By improving property registration rates, blockchain could introduce a bigger supply of asset collateral, which could provide greater downside protection to lenders, and potentially lower the cost of mortgage financing. Our sensitivity analysis suggests that in select LatAm countries where both land registration is low and mortgage rates are high (7%-11%), a 50bps improvement in rates could generate over $6bn in annual savings.

By addressing these inefficiencies, blockchain could fundamentally reshape international real estate markets and introduce significant cost savings. Importantly, we believe blockchain

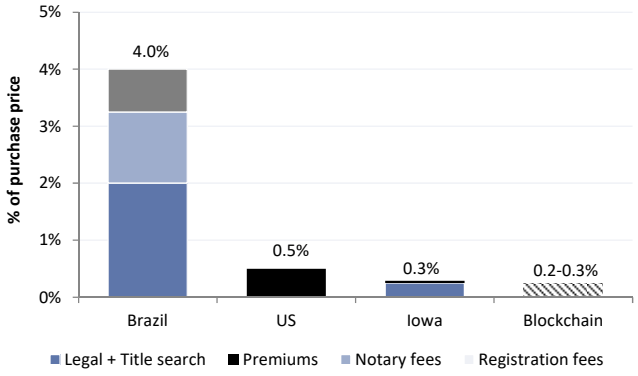
adoption in emerging markets could outpace its adoption in more- developed nations, as many developing nations do not have formal land registration systems in place.

Exhibit 32: Many countries face meaningful inefficiencies as a result of low land registration rates
World Bank land registration index by country; index reflects aggregate ranking of time, steps and costs involved in registering property



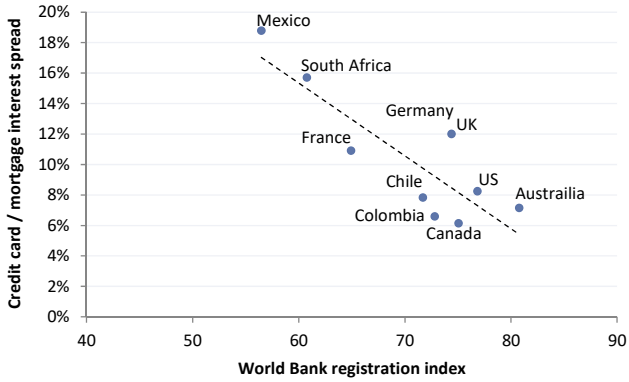
Source: World Bank.

Exhibit 33: Low registration rates contribute to high property transfer fees
Property transfer fees as a percentage of property value



Source: Global property guide, Iowa Finance Authority, Goldman Sachs Global Investment Research.

Exhibit 34: Lack of asset collateral tends to contribute to higher mortgage rates as evidenced by relative spread between secured and unsecured credit rates
Credit card (unsecured) / mortgage (secured) interest rate spread



Source: World Bank, Goldman Sachs Global Investment Research.

Exhibit 35: We believe blockchain could introduce greater asset collateral through improving land registration, potentially lowering interest rates on mortgages
Mortgage interest rate sensitivity

	Registration	Mortgages				Interest expense savings (bn)		
	ranking (0-100)	Total (bn)	% total loans	Rate	Expense (bn)	25 bps	50 bps	100 bps
Brazil	53	$36.3	3.7%	7.0%	$2.6	$0.1	$0.2	$0.4
Chile	72	$623.4	26.1%	8.1%	$50.4	$1.6	$3.1	$6.2
Peru	77	$122.1	16.5%	8.2%	$10.0	$0.3	$0.6	$1.2
Mexico	56	$406.1	15.5%	10.8%	$43.9	$1.0	$2.0	$4.1
Colombia	73	$159.0	10.5%	9.5%	$15.1	$0.4	$0.8	$1.6
Average / total	**66**	**$1,346.8**	**14.5%**	**8.7%**	**$122.0**	**$3.4**	**$6.7**	**$13.5**

Source: World Bank, Goldman Sachs Global Investment Research.

Case Study 4: Capital markets – US cash equities

We believe blockchain could drive greater efficiencies in the US cash equities market, primarily through streamlining the post-trade settlement and clearing processes. By reducing the duplicative, often manual affirmation and reconciliation of trades across buy-side clients, broker-dealers, trust/custody banks, and the Depository Trust & Clearing Corporation (DTCC), we believe blockchain could result in an estimated ~$2 bn in annual cost savings in the US (both explicit and economic costs). On a global basis, the benefits would likely exceed $6bn in annual savings assuming costs are proportionate to market cap. We believe the majority of savings would accrue to banks via lower headcount and back office costs. We expect execution venues to be largely unaffected by blockchain, as price discovery, the need to match counterparties, and anonymity will still be required and the execution process is already fairly efficient today. Although we think broad-scale adoption (if it occurs) could create risks to a portion of revenue generation for trust banks and clearing houses, the process is likely to be evolutionary and not revolutionary, with both entities still playing a role in the ecosystem.

What is the opportunity?

The US cash equities market is the largest and most active equity market in the world, trading an average of 7 billion shares, or approximately $277 bn of notional value, per day in 2015. Throughout the lifecycle of an equity trade, a number of financial intermediaries are required: stock exchanges / trading venues (NASDAQ, NYSE), broker-dealers, custody banks and the Depository Trust Company (DTC, a subsidiary of the DTCC). While the execution of cash equity trades has been streamlined over the years, the post-trade process remains complex and expensive. We believe that blockchain could further streamline the post-trade part of the trade cycle by eliminating duplicative confirmation/ affirmation steps, shrinking the settlement cycle, and reducing trading risk, which in turn should lower the industry's cost and capital needs.

What are the pain points?

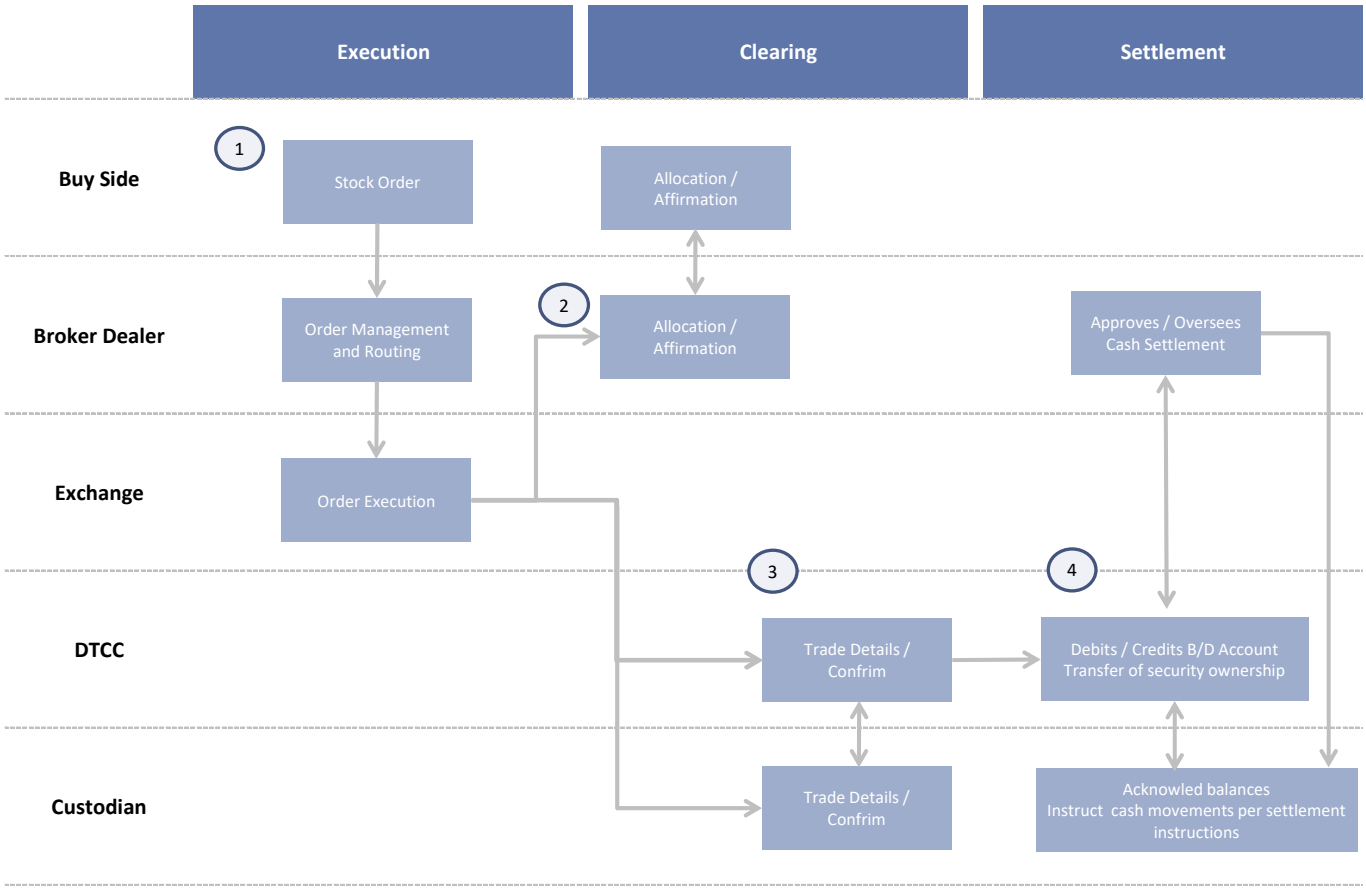
The clearing and settlement of US cash equities has been streamlined over the years and is largely an efficient process today. Still, manual reconciliation and affirmation of trade details across clients, brokers, the DTCC, and trust banks is required before a trade can be processed and settled. Throughout the clearing and settlement process, there are many pain points that could be improved:

- **Multiple versions of the trade.** When multiple parties are involved across a single transaction, multiple versions of the trade can be recorded across the various systems that each party uses. This introduces an element of uncertainty, which can require manual intervention when parties disagree on trade details.
- **The settlement process is long**. While stocks in the US trade in fractions of seconds, the settlement process takes three days (moving to two in 2017), which ties up capital and liquidity.
- **Account information/instructions are constantly changing.** Over time, account information and settlement instructions change (new accounts are opened or closed, account numbers change, custodians change, etc.) resulting in stale information (particularly for standard settlement instructions) requiring increased communication and manual intervention.
- **Operational risk.** Firms encounter extra operational risk in connection with trade settlements that could be eliminated with pre-trade checks via blockchain technology.

What is the current way of doing business?

The end-to-end process of a US cash equity trade can take various paths depending on the type of order and or client (institutional trades (block trade), retail trade, etc.). However, all equities trades are processed by the Depository Trust & Clearing Corporation (DTCC), which serves as the central securities depository and central counterparty, or the hub where all securities positions are held, cleared, and settled in the US. Below is a simplified example of the life cycle of a US cash equities trade through the execution, clearing, and settlement process.

Exhibit 36: Simplified illustration of how US cash equities trade today



Source: DTCC, Goldman Sachs Global Investment Research.

Execution

1. In the simple example above, we provide a basic overview of a simple buy order on behalf of a buy-side investor (mutual funds, pension plans, hedge funds, etc.). When these entities seek to buy stock, orders are sent to their broker/dealer(s) denoting the standard terms – ticker, price, number of shares/ value of order, and any special execution instructions. The broker/dealer then provides order management and routing services, directing that the trade be executed on one or several exchanges (NYSE, NDAQ, BATS) or other execution venues (dark pools) to achieve best execution. The exchange or alternative trading venue serves as the meeting point for all buyers and sellers, providing liquidity and price discovery for market participants.

Clearing

2. Once an order is executed on an exchange(s), the trade confirmation/details are sent to the executing broker and the client to confirm / affirm the details (stock, price, number of shares, value, account / funds, etc.)

3. Following confirmation / affirmation between broker/dealer and client, the trade details are sent/posted to DTCC and shared with custody banks (who are clearing members of DTCC). This allows for both parties to adjust their books to reflect the transaction and upcoming settlement of securities for cash. DTCC will enter the details into its various systems to reflect the trade in its book-entry system, which centralizes equity ownership, transactions, and balances.

Settlement

4. Settlement refers to the exchange of payment to the seller and the transfer of securities to the buyer of a trade – the final step in the lifecycle of a trade. In US equities, settlement typically occurs on T+3 (three days after trade date), although the US is moving to a T+2 settlement process by 2017. DTCC (through its subsidiaries) aggregates the debits and credits across all trades and provides a net balance that needs to be satisfied by a client's settling bank. Each bank acknowledges the net balance owed or to be received. Once that occurs, DTCC (via the Federal Reserve) posts the applicable debit or credit to the settling banks; once payments are confirmed by the Fed, settlement is complete.

How can blockchain help?

We believe most of the benefits that blockchain could bring to US cash equities trading are in the clearing and settlement processes, specifically: reducing or eliminating trade errors, streamlining back office functions, and shortening settlement times:

1. **Reducing / eliminating trade errors:** We estimate that roughly 10% of trading volume requires some manual intervention based on our conversations with industry participants, but this could vary across organizations given differences in client bases and order flow. While many of these issues are resolved without major issue, they still require manual intervention outside of normal broker/dealer/DTCC/custodian's processes. With blockchain, records require authentication / verification across all nodes of the network, which should eliminate the need for manual intervention. Essentially, by enforcing agreement at the time of entry, blockchain could eliminate some of the most common post-trade issues and errors, such as incorrect settlement instructions or incorrect account/order details. Today, these details are confirmed / affirmed by multiple parties (DTCC, custodians, broker/dealer, clients) and multiple times throughout the lifecycle of the trade. If blockchain could be fully implemented across these parties, many of these attributes could be included in a smart contract, thus becoming a pre-trade requirement to execute an order rather than a downstream, post-trade check that requires multiple parties to agree.

2. **Streamlining back-office functions:** We believe that blockchain could significantly streamline back/middle office activities through reduced headcount and fewer platforms/systems, reflecting the reduction in trade errors/issues and elimination of manual reconciliation. Exhibit 45 above is a very simplified example of the process, as a real-life example would have many touch points and people involved with trade reconciliation and issue resolution.

3. **Shortening settlement times:** Finally, we think blockchain can reduce settlement times and thus reduce the risk in the system. While we don't think real-time settlement is realistic for all market participants (e.g., market makers), we do believe that settlement

times below T+3 (T+2 in 2017) would reduce the amount of risk in the process as well as the amount of capital that broker/dealers commit to unsettled, outstanding trades.

Quantifying the opportunity

We see two primary areas where costs could be reduced across US cash equities - capital requirements and expenses (headcount, systems, clearing):

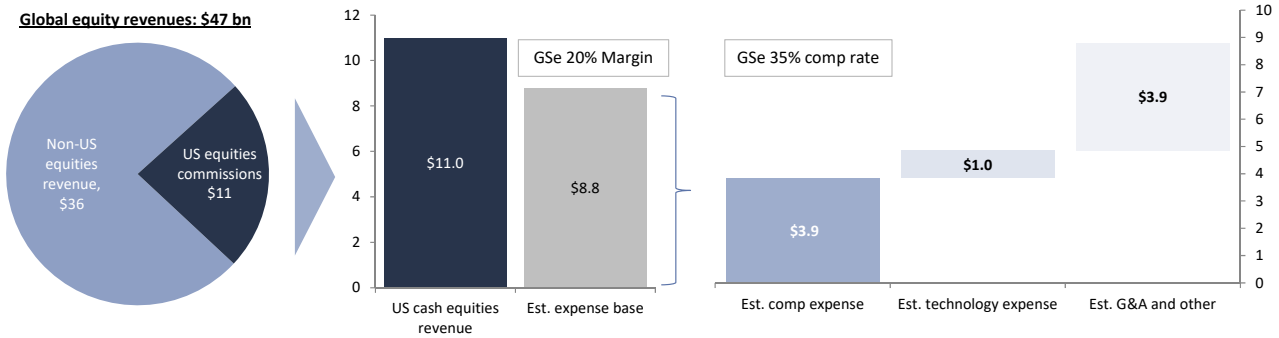
Overall, we think blockchain could reduce total expenses by ~$2bn at the midpoint, with ~$650mn-$900mn in lower compensation costs due to lower settlement/clearing headcount and $500-$700mn in IT systems savings. When we include economic cost savings of lower capital commitments at DTCC, we arrive at an additional $500mn in economic savings.

If blockchain technology is fully implemented across the ecosystem, fewer people and technological systems will be required to process, clear, and settle trades. These savings will be spread across banks, broker-dealers, trust banks, and the DTCC – as the distributed ledger technology reduces (and potentially eliminates) the manual intervention required in equities trade processing. For example, numerous systems at the DTCC are required to execute the settlement process for order input (NSCC, DTC Client Input, DTC Pledge System, OMGEO ID), processing (Inventory Management System, Account Transaction Processor), and settlement (NSCC and Settlement Systems). In addition, all broker-dealers use a combination of proprietary technology and third-party systems to process equity trades. In a post-blockchain world, we believe that many of these systems will be redundant, as smart contracts provide all relevant information for trade processing and settlement. In the two sections below, we look more closely at how blockchain could affect expenses and capital requirements:

1. Expenses: We estimate $1.4bn in reduced expenses

We estimate that US equity trading commission revenue is ~$11bn annually within the overall global equity trading revenue pool of ~$47 bn in 2015. Assuming a typical 20% pre-tax margin, this implies roughly $8.8 bn in expenses within US cash equities businesses. Assuming an industry average 35% compensation-to-revenues ratio, we estimate roughly $4 bn in total compensation expenses. The remaining expense base is composed of ~$1bn in IT/technology expense based on our estimate of 5% of the total banking sector IT spend in 2015 according to IDC and ~$4 bn of G&A / other expenses.

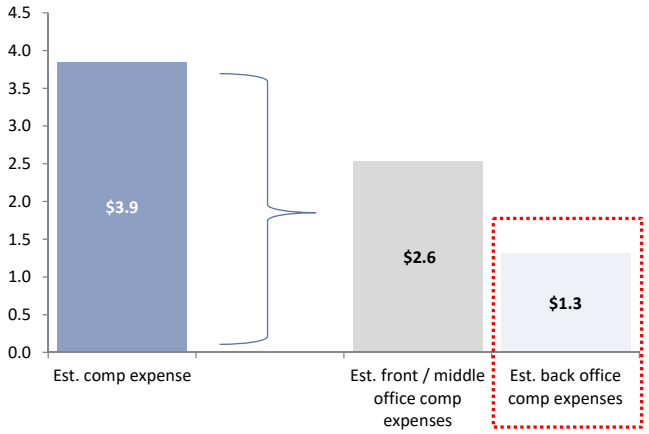
Exhibit 37: Blockchain could reduce the GSe $9 bn annual expense base in US cash equities trading
GSe global equity revenue, expense base and composition ($bn)



Source: Company data, IDC, Goldman Sachs Global Investment Research.

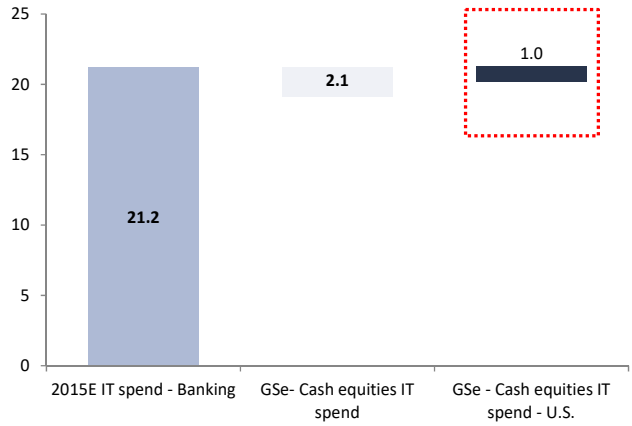
We focus our analysis on compensation and IT expenses, as we believe blockchain will significantly reduce the amount of resources required to settle and clear transactions. Thus, we estimate $1.3bn in compensation expenses that are directly tied to back-office clearing and settlement, or roughly 33% of the $4bn comp pool. On the IT side, we estimate that $2.1bn, or roughly 10%, of total IT spending for the banking sector in 2015 is related to equities trading globally. Of that number, we estimate that 50%, or $1bn, is used within US cash equities trading. Combined, this gives us a $2.3bn expense base that can be reduced / replaced with distributed ledger technology.

Exhibit 38: We estimate $1.3**bn in compensation expenses are tied to back office/ clearing & settlement...**
GSe US cash equities compensation expenses ($bn)



Source: Goldman Sachs Global Investment Research.

Exhibit 39: ...and $1bn in IT spending directly related to US cash equities clearing & settlement, or 5% of spend
GSe clearing / settlement compensation expenses ($bn)



Source: IDC, Goldman Sachs Global Investment Research.

Because the vast majority of back office costs (both labor and IT) in cash equities are tied to manual reconciliation of conflicting trade data, we believe that blockchain could drive the greatest direct cost savings in this area. In addition, we believe the vast majority of these costs are proportional to the volume of trades that need to be resolved based on our discussions with industry participants. Today, roughly ~10% of trades are subject to manual reconciliation, and we believe blockchain could substantially eliminate manual reconciliations as a result of accurate information capture and dissementation at the time of execution. Based on this assumption, we believe pure back office costs for cash equities (labor and IT) could be potentially reduced by over 50%. We provide an illustrative sensitivity analysis below based on a range of 50% - 70%. At the mid-point of our range, we estimate a 60% expense reduction in back office costs, yielding ~$1.4bn in savings. This equates to roughly 16% of the estimated total cost base in US cash equities trading.

Exhibit 40: We estimate a 16% reduction in total costs (~$1.4bn in annually) in US cash equities amid reduction in IT and back-office compensation, enabled by blockchain

GSe US cash equities savings as % of total cost base given range of savings on back office IT and comp. expenses

IT Spend in US Equities - $1bn total / Range of Savings via blockchain	Back office compensation - $1.3bn total: Range of Savings via blockchain 50%	55%	60%	65%	70%
50%	13%	14%	15%	15%	16%
55%	14%	14%	15%	16%	17%
60%	14%	15%	16%	16%	17%
65%	15%	16%	16%	17%	18%
70%	15%	16%	17%	18%	18%

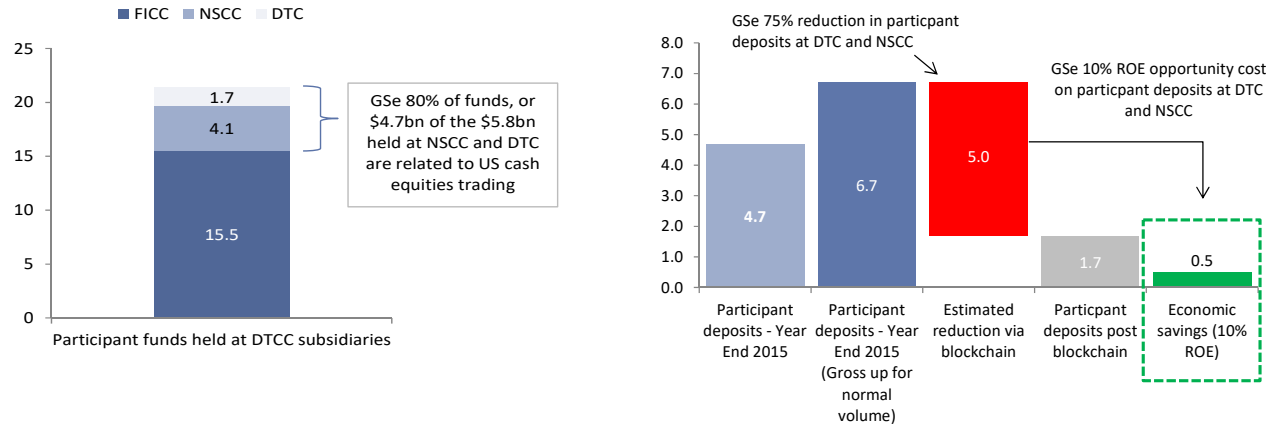
Source: IDC, Company data, Goldman Sachs Global Investment Research.

2. Lower capital requirements:

In addition to reducing explicit costs involved with clearing and settlement, we believe blockchain could also yield substantial economic savings by reducing the aggregate amount of capital required at clearing houses. To help frame the potential opportunity, we show an illustrative example below acknowledging that a range of outcomes exist depending on ROE assumptions, capital reduction, trade volumes, etc.

In US cash equities, the relevant clearing houses are the Depository Trust Company (DTC) and the National Securities Clearing Corporation (NSCC). At year-end 2015, DTC and NSCC had a combined $5.8bn in participant deposits. Because DTC and NSCC also clear and settle other securities (e.g., munis, corporate debt), we estimate that 80% of the funds are related to equities, or $4.7bn. Since this value is for the year-end 2015 quarter, we gross this up by 30% to reflect seasonally soft volumes in December based on publicly available US equity exchange data. Thus we arrive at $6.7bn in participant deposits related to US cash equities on average. Of this, we estimate that 75% (midpoint of industry range) could be eliminated with the implementation of blockchain technology, shortening the settlement cycle and, in turn, the need for capital in the clearing house. Again this is a hypothetical example that relies on our assumption and could vary significantly depending on how blockchain is utilized in US cash equities. Assuming a 10% ROE (a typical industry target), we believe the $5bn in capital savings translates into roughly $500mn annually in economic savings for broker-dealers.

Exhibit 41: We estimate $5bn reduction in capital required at DTCC clearing houses; economic savings of ~$500mn assuming a 10% ROE opportunity cost
Participant deposits at DTCC subsidiaries at year-end 2015 ($bn); GSe econ. savings due to lower capital required at DTCC ($bn)



Source: DTCC, Goldman Sachs Global Investment Research

Who could be disrupted?

We believe blockchain technology will mainly be a source of cost savings and efficiency improvement for capital markets, as opposed to a new competitive force capable of disrupting the market position of incumbents' profit pools. We see blockchain and distributed ledger technology as primarily affecting the "post trade" part of the ecosystem as opposed to pre-trade/execution services. Below we highlight potential implications for various parts of the trading ecosystem.

Exchanges

We believe the risk of disruption to exchanges from a broad-based implementation of blockchain is fairly limited owing to both practical and technical factors. Exchanges have evolved dramatically over the years, with technological advances materially reducing market participants' costs and increasing execution speed. For example, the average latency to process an order message at BATS decreased 94% between 2007 and the end of 2015 – from over 930 microseconds to ~57 microseconds. The cost of execution has also plummeted over time. Thus, today's cash equities execution process is already quite efficient, limiting blockchain's usefulness in this regard. And from a technical perspective, the application of blockchain does not solve two key aspects of trading provided by exchanges – anonymity and price discovery. Moreover, with already significant fragmentation in US cash equities markets (currently there are 13 US stock exchanges and 72 alternative trading systems), additional venues would only increase complexities of today's market structure, in our view.

Custody banks

If distributed ledger technology (blockchain) takes hold and the existing system is completely overhauled, we believe the custody banks could face modest revenue risks in both fees and net interest income over the long term. However, complete disintermediation is far from certain, and we would expect the trust banks to play a key role in the industrial-scale adoption of blockchain, acting as a trusted counterparty to market participants and driving expense efficiencies that the new technology creates.

At their core, custody banks ensure the accuracy of the receipt/delivery of securities and cash on behalf of customers by acting as an intermediary between institutional investors,

brokers, and clearinghouses. Significant infrastructure investments over the last several decades and regulation created a deep moat around custody businesses, which are now concentrated with only a handful of banks (the top five banks control over 50% of business globally). However, over time the models for custody banks have evolved from core custody, clearing/settlement and record keeping functions to include higher value-added services such as (1) fund administration & accounting (daily pricing, reporting, compliance); (2) middle office (portfolio administration, risk analysis, performance attribution, collateral management); and (3) capital markets services (securities lending, cash management, collateral transformation, FX trading). Excluding net interest income revenues, we estimate global securities services revenue amounts to a total of $26bn for the largest custody banks.

Exhibit 42: Custody banks' core functions

Custody Banks - Core Functions	
Services	**Overview**
Custody	• Global custody for mutual funds, hedge funds, other asset owners • Asset servicing including corp. action processing, income processing, proxy services, trustee services
Clearing & Settlement	• Cash and derivatives clearing across listed and OTC markets • Bilateral & central clearing • Cross-border settlement
Fund Administration	• Fund accounting & administration including NAV calculation, pricing and reporting • Compliance monitoring and reporting
Fund Distribution	• Processing of subscriptions and redemptions • Transfer agent
Issuer Services	• Issuer & shareholder services • Escrow & agency services
Middle Office Services	• Portfolio adminstration including trade support, risk analytics, KYC, performance attribution and pricing • Outsource solutions for both mutual funds and hedge funds
Liquidity Management	• Securities lending and borrowing • Collateral optimization and transformation • Cash management / treasury
FX Management	• FX spot and derivative execution on behalf of clients

Source: Company data, Goldman Sachs Global Investment Research

We believe most of the services outside of the "core custody" functions will continue in their current form, though there could be a risk of "unbundled" pricing. Certain fees associated with pure custody, the confirmation/affirmation process, corporate actions, book entry, and more-labor-intensive instruction charges could become obsolete if distributed ledger technology is widely adopted; meanwhile, a more efficient/faster settlement process could require less "idle" cash on the sidelines, weighing on the group's net interest income. That said, these fees could be replaced by new fee-generating services (such as providing access to new technology), while a sharp reduction in the cost burdens of trust banks should minimize the impact on their bottom lines. Importantly, the trust banks are actively exploring the early development and implementation potential of blockchain in order to be ready if the new infrastructure takes hold. Many of the trust banks under our coverage are already working to incorporate blockchain technology into their processes. For example, State Street has been testing immutable records technology that includes blockchain-like features such as data enrichment (tagging data to help create smart contracts), peering (communicating and authentication concepts to ensure communication across ledgers), and adaptive ledger technology (enabling public and private ledgers to communicate). Also, Bank of New York Mellon and Northern Trust are actively exploring blockchain technology and how it can optimize their current processes across custody and servicing.

Clearing houses

We believe the capital markets are still likely to require clearing houses after the implementation of blockchain for two major reasons: (1) transactions will likely require novation to achieve netting and reduce counterparty credit risk; and (2) regulators could have concerns about removing the "safety net" of central clearing entirely.

On the first point, a complete pre-trade verification would essentially allow trades to settle right away (T+0) in cases where the settlement is the actual trade. Theoretically, this would eliminate the need for a central clearing party (such as DTCC in cash equities). However, this process would also eliminate the benefits of netting, which remains core to today's market structure, where electronic market makers/high-frequency traders account for the vast majority of trading. Notably, DTCC has said that by netting trades and payments among market participants, it reduces the value of securities and payments that need to be exchanged by an average 98% daily.

On the second point, after 2008, global regulators increased their focus on minimizing systemic risks, which led to an increased push toward central clearing. Blockchain could reduce counterparty risk significantly via pre-trade verification; however, we believe regulators would want a central body to oversee the trade and minimize default risk.

Overall, we believe clearing houses will likely be an additional oversight of the blockchain-driven system as part of the settlement infrastructure and an independent verification body.

Challenges to adoption

While broad-based blockchain adoption could result in numerous savings across capital markets, many obstacles could prevent realization of the technology's full potential. We highlight some of the obstacles below:

1. **Universal adoption:** To achieve a positive network effect and reap all the benefits of blockchain technology, all capital market participants (banks, broker/dealers, DTCC, clients, etc.) will probably need to adopt a uniform standard across the ecosystem. Thus competitors will have to collaborate with one another, and agree on how and when to universally adopt the technology.
2. **Standardization:** All market participants will have to agree on how to standardize the entire capital markets system across various asset classes, covering everything from basic settlement information to account information, trading records, order information, and other data.
3. **Scalability:** To successfully scale the technology, significant investments in infrastructure and processing power will be required to handle the billions of transactions / messages per day. Thus the various banks, broker-dealers, clients and other parties will need to make major capital investments to achieve the safety, security, and robust performance that market participants demand.
4. **Legal and regulatory approval/changes:** Widespread adoption of blockchain technology will likely require significant coordination and cooperation among global regulators. Also, new regulatory requirements or changes to existing rules may be required to fully implement the system across asset classes and for cross-border transactions.
5. **Anonymity requirements:** Because capital market participants require anonymity, separate records for each participant are likely to be required outside of the blockchain. However, certain regulatory information (e.g., KYC, AML details) will probably need to be attached to each transaction to streamline the process.

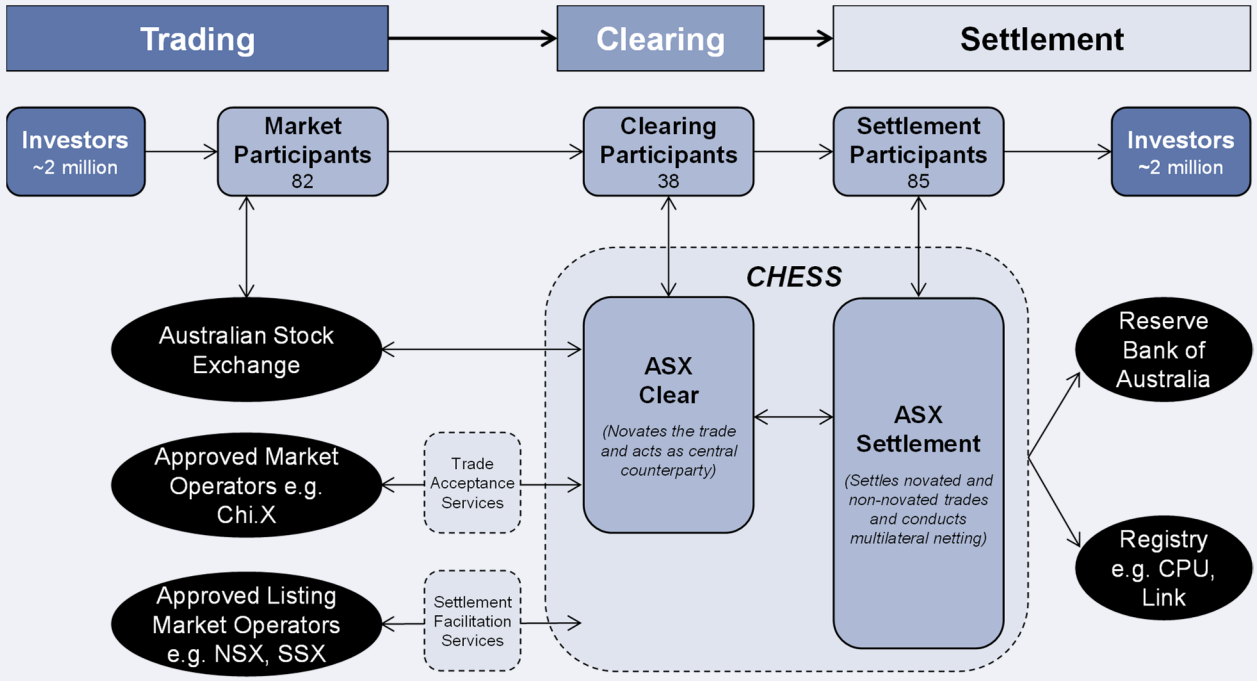
6. **Challenges of technical transition:** Transitioning trillions of dollars of transactions to a new system will involve an enormous amount of testing and/or running parallel systems. Thus market participants will need to devote a significant amount of time and capital to the process in order to minimize operation risks.

ASX: A real-world blockchain testbed for post-trade services

The ASX (Australian Securities Exchange) has announced that it is working with Digital Asset Holdings to determine whether blockchain can be used to replace CHESS (ASX's clearing and settlement system for cash equities, and the electronic sub-register of these securities). This development appears timely, as CHESS was nearing its scheduled "end-of-life" (even though it remains very stable), and blockchain has begun to mature at the same time. We believe Australia is a particularly good testbed for blockchain, because the system is dematerialized (no physical share certificates) and clearing/settlement is currently centralized (though clearing competition has just been notionally approved, so any system will need to be designed for this). Australia's economy was also relatively sheltered from the global financial crisis, so many key stakeholders are better equipped to cope with technological change. Australia's banking system is stable, and many local banks have demonstrated their interest in blockchain technology. Specifically, three of the four largest domestic banks are part of R3 (an industry consortium comprising more than 40 global banks and technology companies focused on enabling the adoption of blockchain), and the fourth is directly involved with the Hyperledger project. Some of these banks are also reported to have trialed other solutions, such as Ripple.

The ASX is the main venue for cash equities trading, clearing, and settlement in Australia, and the listing platform for stocks in the key benchmark indices (e.g., S&P/ASX 200). Competition in trading in ASX-quoted equities began in October 2011 with the launch of Chi-X (which has since stabilized at ~18% market share). Clearing and settlement services continue to be provided by ASX Clear and ASX Settlement via a system known as CHESS, and Chi-X has access to this via a Trade Acceptance Service (TAS). In March 2016, the Australian government agreed to allow competition in equities clearing, subject to a variety of conditions. If a committed clearing competitor emerges, it could take 18 months for a license to be approved (though no competitor has come forth at this stage). A few other small exchanges also exist (such as the listing and trading venues of NSX, SIM and SSX) and these use CHESS for settlement via the Settlement Facilitation Service. CHESS also provides an electronic sub-register of securities, with name-on-register capabilities (not just via custodians).

Exhibit 43: Illustration of ASX's role in the Australian equities market
Includes simplified description of key systems.



Source: ASX.

Post-trade technology upgrade – traditional vs. blockchain: The ASX announced in February 2015 that it would replace and upgrade a number of its platforms, including CHESS. However, it noted that a vendor decision would be delayed on CHESS until there was greater certainty around whether equities clearing competition would be permitted. ASX management subsequently indicated that it was simultaneously investigating distributed ledger technology (DLT)/blockchain as a post-trade solution. We believe that ASX interacted with a very large number of blockchain technology providers in 2H15, who were asked to provide demonstrations. It selected Digital Asset Holdings. In January 2016, ASX announced that it had joined a number of other companies in a funding round for DAH, with the ASX paying A$14.9mn to acquire a 5% stake, fund an initial phase of development, and acquire a warrant that gives ASX the right to purchase further equity (about 5%) and appoint a director to Digital Asset Holdings' board.

Timeline for assessment: ASX has stated that it will take the first 6-12 months to develop a prototype solution and work with regulators and participants on the initial design. While ASX may provide updates on its progress at any number of public events over the rest of 2016, we expect to receive some material comments after FY16 results are released in August. ASX hopes to make a final decision after about 18 months (mid-2017). Since it is still early in the process (both in ASX's plans and for blockchain technology), ASX has not yet devised an "implementation roadmap" beyond this point. However, it has said that it wants to gain acceptance from the key participants that form its "Business Committee" and then work with other smaller players on how best to transition them. ASX has said this could take 10+ years, though we think ASX hopes to achieve it far more quickly.

CHESS will continue to operate as usual during the above process. We also note that the ASX has recently selected Nasdaq's Genium INET Clearing platform (which ASX already uses for futures clearing) if it decides not to proceed with blockchain in cash equities.

Blockchain (distributed ledger) benefits: ASX's advisors have estimated that the implementation of blockchain for Australian equities post-trade could result in **annual savings for end users in the industry of up to A$4-5 bn**. This includes exchanges, regulators, participants, custodians, nominees, data vendors, and technology providers. Some of these savings will reflect a reduction in back-office administration and compliance costs, while some will reflect a reduction in risk (and hence capital) if the settlement system is closer to real-time.

ASX acknowledges that less clearing might be needed (cash equities clearing currently represents ~A$45-50mn of ASX's revenues), but it believes now is the right time to pursue this opportunity, rather than investing in a new infrastructure that could potentially become quickly outdated.

ASX is also optimistic that blockchain could enable other services (e.g., real-time dividend payments, voting and register analysis; more-efficient tax returns), thus encouraging post-trade innovation by other parties. While the introduction of a Digital Identity for Australians (perhaps implemented by the Australian Tax Office or Australia Post) would enhance these possibilities, ASX's project does not depend on this.

Other technical aspects: ASX's implementation will be a private/permissioned blockchain. While a beta version is currently being built (with an "industrial strength" version to follow), ASX has stated that it has yet to commit to key elements of the system (e.g., how consensus is formed; who participates in setting consensus; who has access to reading/editing the data; whether or not the ledger is actually "distributed").

We also note that the ASX recently moved from T+3 to T+2. ASX believes that blockchain may actually allow for a choice of settlement times (with some approaching T+0). It is uncertain how this might affect the efficiencies of netting or short selling.

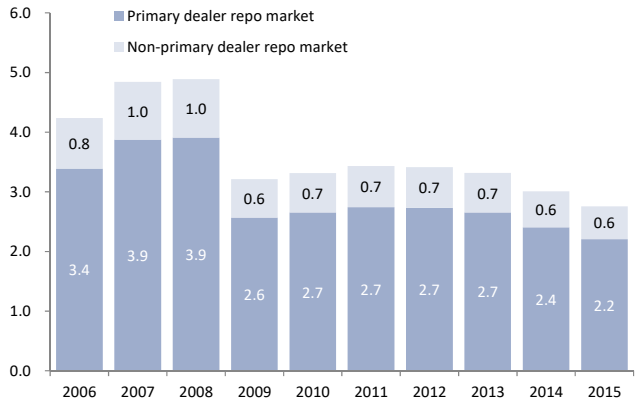
Case Study 5: Capital markets – Repo

We believe a clearing solution for the $2.8tn US repo market could yield approximately $5bn in economic savings per year for the industry. Blockchain technology could help make the process more efficient – though it would not be a cure-all. The savings would be a result of greater netting benefits for banks and broker/dealers. Blockchain could help facilitate the repo clearing process by streamlining the multiple movements of cash and collateral over the life of a repo contract.

What is the opportunity?

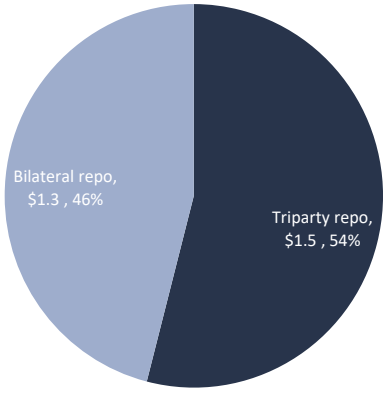
The US repo market totaled ~$2.8tn in average outstanding borrowings per day in 2015. By way of background, a repurchase agreement, or "repo," is effectively a collateralized loan, and it is usually secured with high-quality securities like US Treasuries or agency MBS. Typically, one counterparty provides another with cash for a fixed period of time, with the borrower providing securities as collateral and promising to repurchase them at a future date at a higher agreed-upon price. The opportunity for blockchain would be to streamline the repo process and create greater efficiencies locating collateral, minimizing settlement and trade failure risk, and reducing the overall capital commitments for banks. Ultimately, this higher level of efficiency would increase liquidity in the market, decrease counterparty risk, and optimize capital utilization.

Exhibit 44: We estimates $2.8tn in average daily repos outstanding
Average daily repo amount outstanding, $ tn



Source: SIFMA, Federal Reserve Bank of New York, Goldman Sachs Global Investment Research

Exhibit 45: The market is split roughly 50/50 across bilateral and triparty repo
Breakdown of repo outstanding: bilateral vs. triparty, $ tn



Source: Federal Reserve Bank of New York , Goldman Sachs Global Investment Research

What are the pain points?

The repo market serves as a crucial source of funding for the financial community, and is critical for clearing and settlement activity in the US financial markets. Various capital rules following the 2008 financial crisis created meaningful hurdles in this market, most of which could be solved with a uniform clearing solution for the repo space. Although the industry will need to consider many factors before the various parties can agree on how to clear repo transactions, we believe blockchain technology could help streamline the current processes. Below we highlight a few of the specific pain points that characterize the repo market:

- **Capital rules have raised the cost of repo activity.** Capital rules and regulations – particularly the supplementary leverage ratio (SLR) – have resulted in banks optimizing their balance sheets and reducing their repo books by an estimated $1tn since 2013, as the 5% capital requirement exceeds the low ROE on repo books.
- **Structural mismatch of liquidity.** Cash lenders (money market mutual funds, institutions) typically seek overnight repo, whereas collateral borrowers (REITs, hedge funds) prefer longer-maturity borrowing, thus creating a structural mismatch in assets and liabilities for dealers.
- **Timing and settlement risk.** The repo market is often accessed in real time by broker-dealers seeking liquidity or specific collateral, with the settlement, clearing, and netting processes happening in multiple sequential steps. This increases operational complexity, with numerous cash and collateral movements throughout the day to meet funding and contractual requirements.
- **Collateral management.** Repos vary in terms of the type of collateral required to settle the transactions. While collateral complexity cannot be eliminated, the operational inefficiencies for broker-dealers and clients in terms of locating and settling collateral could be streamlined.

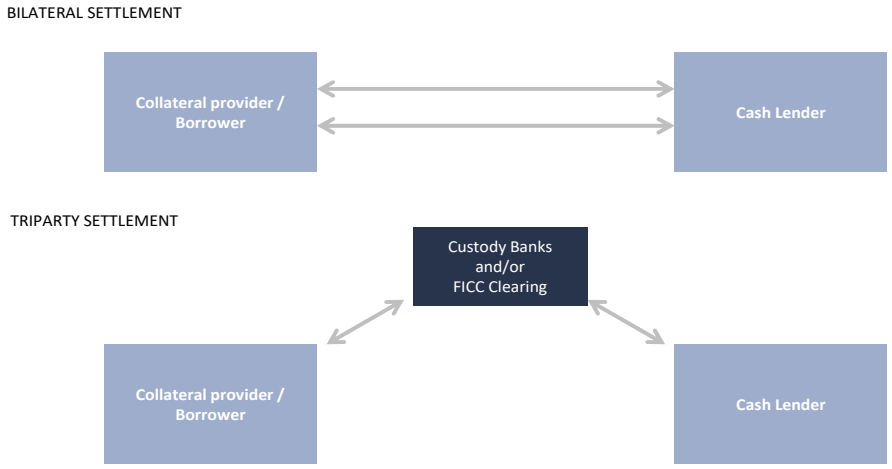
What is the current way of doing business?

The repo market today operates in essentially two verticals: (1) bilateral repo and (2) triparty repo. According to the Federal Reserve Bank of New York, the triparty repo market has ~$1.5tn (54% of total) of average daily amount outstanding while the bilateral repo market has ~$1.3tn (46% of total).

Bilateral repo agreements are negotiated between two parties (typically directly) and require multiple movements of cash and collateral to open and close the trade. According to the Federal Reserve Bank of New York, dealers prefer to use bilateral repos to acquire securities, giving them the ability to re-pledge securities and provide funding to their clients.

Triparty repo agreements are custodied and settled on the books of clearing banks (BK, JPM), whereas cash and securities are moved between cash lenders' and securities lenders' respective accounts. The custody banks act as agents, ensuring that the terms of the contract are upheld. Custody banks effectively perform back-office operations for both borrower and lender, helping to protect against settlement risk and enabling flexible collateral management. Lastly, a General Collateral Financing (GCF) repo is a form of tri-party repo where DTCC's Fixed Income Clearing Corporation (FICC) acts as central counterparty, providing netting benefits to securities dealers/members.

Exhibit 46: Repo transactions settle on either a bilateral or a triparty basis
Bilateral and triparty settlement



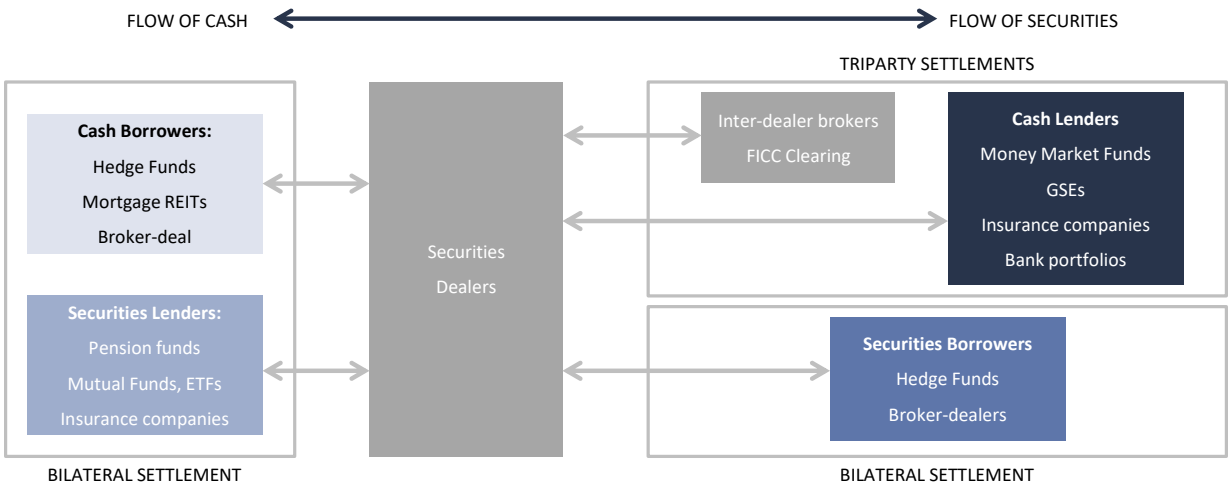
Source: Federal Reserve Bank of New York

Who uses the repo market?

Borrowers typically use the repo market to access liquidity, finance securities positions or obtain leverage. Firms such as hedge funds or mortgage REITs usually engage dealers to access the repo market. Securities dealers provide collateralized financing to their clients and re-pledge securities collateral to obtain funding from lenders. As dealers intermediate the supply and demand of liquidity, bilateral repo is typically used to provide funding to others, while triparty repo is used to fund the dealer.

Cash lenders (or cash investors) use repo as a way to securely invest cash. Lenders may include pensions, money market mutual funds, insurance companies and other short-term cash accounts/corporate treasuries, as well as financial institutions, such as banks and broker-dealers. According to the Federal Reserve Bank of New York, cash lenders often use the triparty platform for its operational efficiencies, estimating that more than half the cash invested in the triparty repo market comes from money funds' and securities lenders' reinvestment accounts.

Exhibit 47: Greater efficiencies in the repo market would facilitate greater flow of liquidity across capital market participants
Key repo market participants



Source: Federal Reserve Bank of New York, Goldman Sachs Global Investment Research

How does blockchain help?

We believe most of the benefits that blockchain could bring to repo trading stem from capital savings at banks owing to clearing/netting and from more efficient trade processing. Specifically, we see three areas where blockchain could improve the repo process: (1) capital savings at banks via increased netting; (2) faster execution of repo trading; and (3) more efficient clearing and settlement:

1. **Capital savings at banks via increased netting.** Global bank regulations have been increasingly focused on reducing leverage and improving liquidity across the industry. This has caused banks to cut back on their repo activity as the new leverage requirements have lowered the ROE potential for this business. According to the Federal Reserve, the following regulatory changes have reduced banks' involvement in the repo market:
    - **Liquidity Coverage Ratio (LCR)** – The Basel III banking rules' liquidity coverage ratio makes it more costly for bank holding companies and their subsidiaries to obtain short-term repo funding for low-quality collateral.
    - **Supplementary Leverage Ratio (SLR)** – The enhanced supplemental leverage ratio, which is binding on several large US banks, includes leverage incurred through repo borrowings.
    - **Net Stable Funding Ratio (NSFR)** – The net stable funding ratio is intended to encourage banks and their affiliates to extend the duration of their liabilities, thereby reducing their dependence on short-term wholesale funding sources.

Overall, we believe that utilization of a broad-based clearing solution could lead to greater capital efficiencies across the banking industry, potentially increasing the amount of repo that is netted today to 50%-60% of the total reported market. Increased netting at the dealer level would reduce the asset side of dealer balance sheets and thus reduce the amount of capital required.

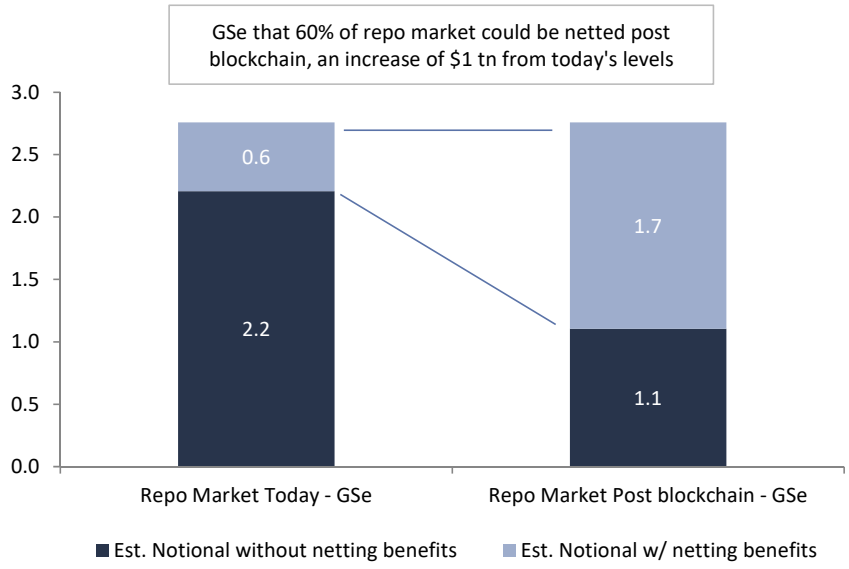
2. **Faster execution of repo trading.** Blockchain technology could accelerate the execution of repo trading, as counterparties would be able to agree to terms and pricing in real-time and smart contracts could more effectively capture collateral requirements.
3. **More efficient clearing and settlement.** Similar to other asset classes, blockchain could enable near real-time repo clearing and settlement, in our view. Blockchain's distributed ledger could enhance information sharing, providing all trade details to all parties almost immediately after execution. This would likely enable counterparties to agree to repo trade details much more quickly, lowering risks and costs. This is the focus of Digital Asset Holdings' partnership with DTCC, which aims to apply blockchain technology to the repo market, so that participants can keep track of collateral and cash movements in real time.

Quantifying the opportunity

We estimate that blockchain could result in $5bn in economic savings owing to the $1tn increase in the amount of repos that could be netted across the Street, reducing capital requirements by $50bn under the 5% SLR requirement.

We estimate that 20% of the repo market today is netted, allowing banks to offset assets and liabilities with the same counterparties and/or opposing legs of repo trades. This equates to roughly $600bn of the total $2.8tn repo market. To help frame the potential opportunity, we show an illustrative example below acknowledging that a range of outcomes exist depending on the share of the repo market that could be centrally cleared/netted, repo market volumes, etc. Based on our conversations with industry participants, 50% - 70% of the repo market could be centrally cleared and thus netted. Using these estimates, we estimate that this would equate to approximately $1.4-$1.7tn in repo trades that could be netted.

Exhibit 48: We estimate that another $1tn in notional repos could be netted down, reducing capital requirements on dealer balance sheets
US repo market: Notional with and without netting benefits ($ tn)



Source: Federal Reserve Bank of New York, Goldman Sachs Global Investment Research

Under the SLR requirement, banks are required to hold 5% capital against their asset base. Thus, any netting benefits in the repo market will reduce the amount of capital required as the gross asset values will be reduced. If we assume hypothetically that 60% of the repo market can be netted down and a typical 10% ROE opportunity cost, we arrive at ~$5bn in economic cost savings in the repo market.

Exhibit 49: Assuming a 10% ROE and a 5% capital buffer under SLR, and also assuming that 60% of the total repo market can be netted, we estimate ~$5.6 bn in capital savings
GSe Repo Capital Savings under various netting and ROE scenarios $ bn

Cost of Capital (GSe 10% ROE) / Range of ROEs	Repo Netting - GSe 20% of Market Today: Range of Repo Market that can be netted down				
	50%	55%	60%	65%	70%
8.0%	$3.4	$3.9	$4.5	$5.0	$5.6
9.0%	$3.8	$4.4	$5.0	$5.7	$6.3
10.0%	$4.2	$4.9	$5.6	$6.3	$7.0
11.0%	$4.6	$5.4	$6.2	$6.9	$7.7
12.0%	$5.0	$5.9	$6.7	$7.6	$8.4

Source: Federal Reserve Bank of New York, Goldman Sachs Global Investment Research

Challenges to adoption

Central clearing may not work for all parties. Although blockchain may help more of the repo market move to a central clearing house, some repo participants might not choose to make the change. For small hedge funds or other small participants, the cost of clearing may outweigh the benefits, ultimately leading them to continue using the bilateral repo market to access the capital / securities they need.

Netting benefits may be lower than estimated. For transactions to be netted, contracts have to satisfy three criteria: (1) same counterparty, (2) same settlement date, and (3) similar collateral. While blockchain may facilitate some standardization of repo contracts and trade conventions, it does not fundamentally change or eliminate the mismatch of terms across repo market participants. Therefore, the level of netting benefits will depend on the alignment of demand / supply in the repo market with congruent terms, and thus may be below our estimates.

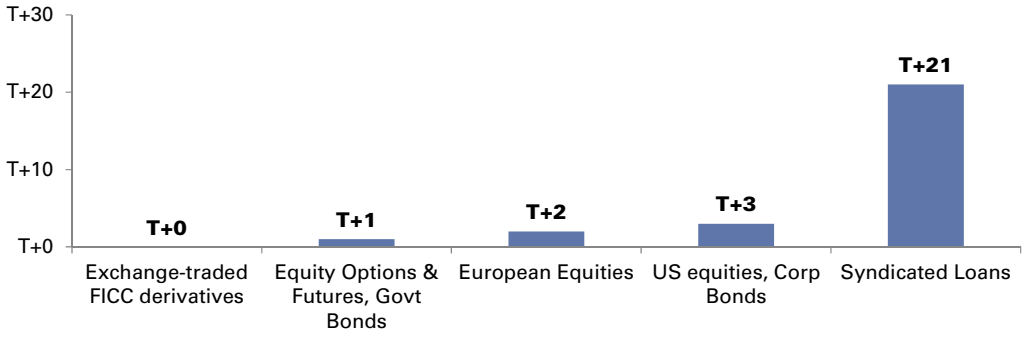
Case Study 6: Capital markets – Leveraged loan trading

We believe blockchain could help reshape the trading of leveraged loans. By enabling the trading of leveraged loans with a distributed ledger, blockchain could streamline and reduce the settlement period to 6-8 days from more than 20 days today (average for the industry). We estimate that blockchain could drive ~$110mn in industry economic cost savings due to a reduction in balance sheet collateral requirements, ~$130mn in annual OpEx savings as blockchain-driven process optimization leads to industry headcount reductions, and ~$50-$60mn in industry funding costs as the trade timeline is reduced. All in, savings could total ~$300mn for the industry under our blockchain scenario.

What is the opportunity?

A leveraged loan, which is a commercial loan provided by a group of lenders, has developed as a way for highly leveraged non-investment-grade companies to gain access to incremental debt. A leveraged loan is initially structured by one or several commercial or investment banks, and then syndicated to other banks or institutional investors. While the industry started during the leveraged buyout boom of the 1980's, it has become the primary avenue for corporate issuers to obtain financing from banks and institutional investors given relatively attractive rates paired with the efficiency of the allocation process. Syndicated loans are less expensive and more efficient to administer than traditional bilateral, or individual, credit lines are. In the US, leveraged loan new issuances totaled $257bn in 2015, $377bn in 2014, and $456bn in 2013. **We believe blockchain could meaningfully lower the current leveraged loan settlement period, introducing significant economic cost and OpEx benefits. This is because banks would be able to redeploy previously frozen capital (due to capital buffer requirements) to earn a greater return on investment, while reducing headcount and shortening the period of time during which funding costs are incurred.**

Exhibit 50: Syndicated loans have by far the longest settlement period
Settlement period by asset class



Source: Procensus, Goldman Sachs Global Investment Research.

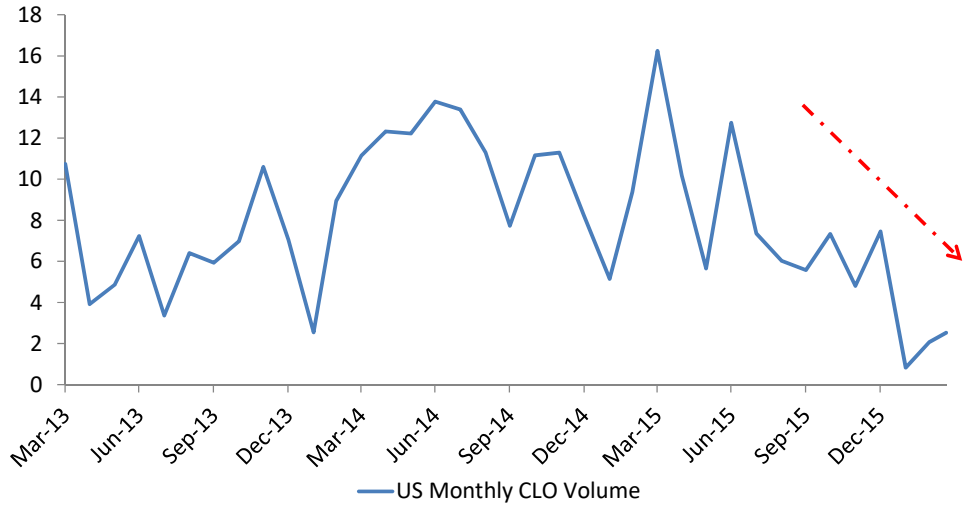
What are the pain points?

We see the opportunity for a material decrease in settlement times from the current T+21 for the industry. This, in turn, could alleviate the required capital buffer, economic, and opex costs.

Leveraged loan settlement processing is costly and complex, requiring intermediary banks to hold capital buffers equal to 1.3% of the notional traded (for instance $13mn for $1bn traded). According to the LSTA, the secondary leveraged loan market traded $590bn in notional volume during 2015. Below we detail key issues for the leveraged loan market:

- **Buy/sell matching:** As banks attempt to mitigate risk, they look to avoid taking on debt from the seller if no buyer has been identified (helping traders limit funding costs) and they try to match buy and sell orders every day. This invariably reduces the market's liquidity as intermediaries limit transaction speed in order to protect their balance sheet exposure and P&L.
- **Obtaining borrower's consent:** When a secondary sale occurs and the lender of record changes, the buyer of the debt must obtain the borrower's consent. This process adds a significant hurdle, and may result in the borrower denying the trade. In this case, the trade may be executed via participation, where the buyer takes a participating interest in the selling lender's commitment.
- **Heightened regulatory requirements (KYC, AML, and FATCA):** The regulatory requirements that financial institutions must fulfill when engaging in transactions has increased substantially since the financial crisis. In particular, this affects the signing of the trade confirm (2.8 days) and agent approval and signature (5 days) steps of the leveraged loan transaction. Specifically, banks have seen increasing regulatory pressure from know your customer (verifying client identity), anti-money laundering (detect and report suspicious activity, including money laundering and terrorist financing), and foreign account tax compliance (FATCA) requirements.
- **Lack of electronic settlement platform:** Currently, brokers are not connected to a central electronic settlement platform that feeds into their internal systems. Moreover, trades are occasionally backdated and do not feed into any system that would make the information broadly available.
- **Disagreement over the economic details of the trade:** Such disagreements are particularly important for the signing of the trade confirmation, which currently extends over three days on average. There is meaningful opportunity for smart contracts to help accelerate the process by enforcing the transaction if predefined parameters are recognized and respected. This is particularly useful for a marketplace involving a large number of counterparties.
- **Risk retention rules have impacted issuance volumes:** On October 22, 2014, the SEC adopted the final rules to implement the Dodd-Frank credit risk retention requirements for asset-backed securities including collateralized loan obligations (CLOs). These rules, which come into effect in late 2016, establish that the CLO manager is the "sponsor" subject to risk retention, and must retain 5% of fair value of the liabilities of the CLO. As a result of this requirement, CLO issuance has dramatically declined (Exhibit 59). Therefore, we believe the industry would view favorably efforts to decrease settlement times – which in turn could yield increased volume and help partly offset the "risk retention rule" impact.

Exhibit 51: Risk retention rules have dramatically reduced CLO issuance volume
US monthly CLO volume – US$ bn

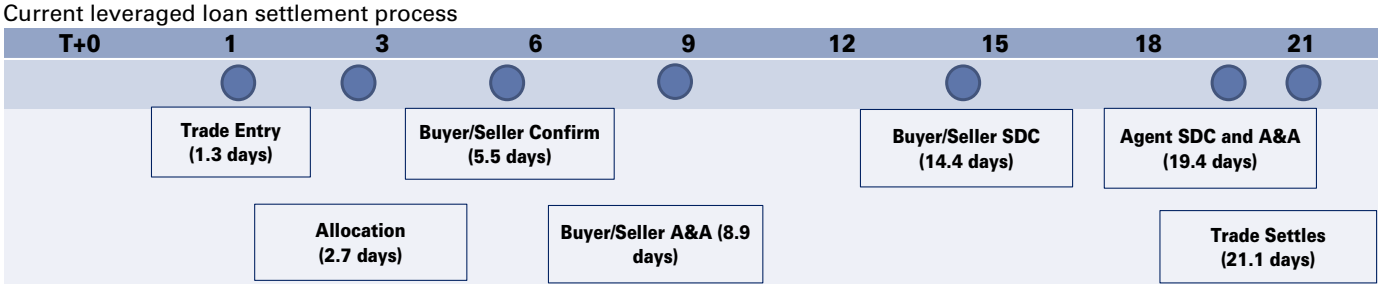


Source: LSTA, Goldman Sachs Global Investment Research.

What is the current way of doing business?

The leveraged loan settlement life cycle involves many phases, spanning approximately 21 days per trade. We briefly detail these steps below:

Exhibit 52: Under current practices, trades take on average 21 days to settle
Current leveraged loan settlement process



Source: Markit Loan Settlement. Note: Data represents 461,500 allocations in 2014.

- **Trade entry**: Trade is entered into a broker-dealer's internal system, which then uploads information to the industry electronic settlement platform (ESP). The information shared with the ESP includes the counterparties' information, the transaction amount, and the price.
- **Allocation**: Buyer/seller logs into the ESP and choses how to allocate the trade to select sub-funds.
- **Buyer/seller trade confirm**: Buyer and seller review the trade in the ESP prior to signing. Once the trade is signed, the trade confirmation, which details the price of the trade, is generated and can be seen by the counterparties.
- **Buyer/seller A&A (assignment agreement)**: The buyer and seller agree on the assignment which shows the trade amount, as well as buyer and seller details.
- **Buyer/seller SDC (settlement date coordination)**: The SDC is a digital confirmation, indicating the buyer and seller are ready to close the trade – allowing the agent to review.

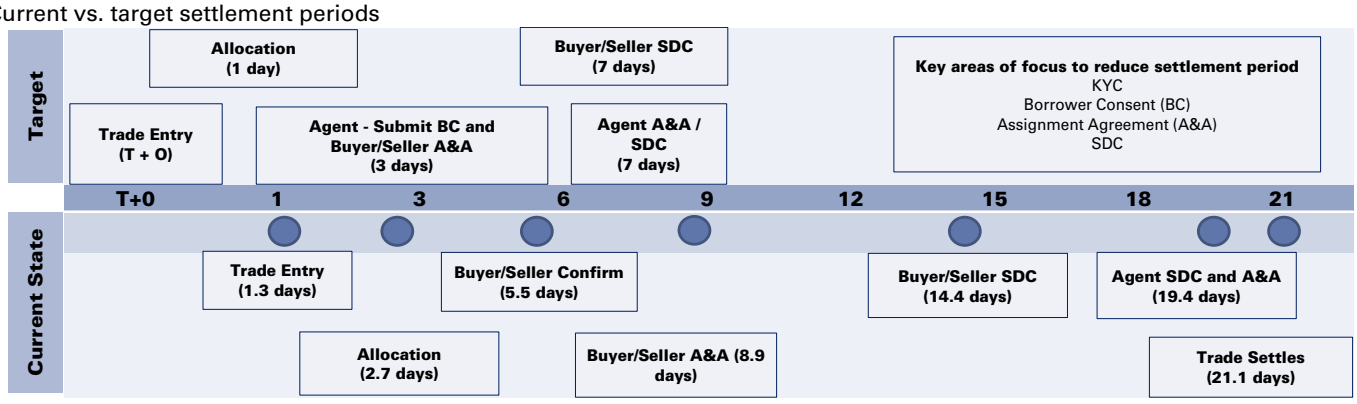
- **Agent SDC and A&A**: Agent (broker-dealer) can review the SDC and A&A.
- **Trade settles:** The buyer sends the seller cash in exchange for the debt. The agent records the trade in the registry showing where the position is held.

In response to extended trade timelines, we highlight that the LSTA (Loan Syndication and Trading Association) has recently proposed a series of actions aiming to reduce the settlement process. On May 4, 2016, the LTSA announced its "Delayed Compensation" initiative, which aims to reduce the buyer's incentive to use the seller's balance sheet in leveraged loan transactions. The new model will require that by T+6, in order to receive delayed compensation, the buyer must: (1) execute the required trade documentation, and (2) select a settlement date of no later than T+7, thereby agreeing to be financially able to settle the trade without interruption until the settlement date. By doing so, we believe this will incentivize the buyer to close a transaction faster. The LSTA expects this initiative to be implemented on July 18, 2016. Importantly, these changes will not alter the fact that trades are often delayed due to KYC checks, and result in partial settlement (which sellers prefer to avoid). However, we think blockchain could make the settlement process more efficient, furthering the LSTA objective of reaching settlement in T+7 days.

How does blockchain help?

Through the digitization of the loan trading process, we see the opportunity for a material decrease in settlement times from the current T+21 timeline. **Blockchain could potentially help shorten the timeline by offering a secured transaction ledger database that all parties would share in a distributed private network.** Blockchain technology is particularly interesting for this market. This is because the notional outstanding values of these loans change regularly **as the debt is pre-payable, making a transparent and easily accessible ledger particularly attractive.** The blockchain is immediately updated to account for any transaction and to reflect changes in ownership in an efficient manner. We note one potential problem area: A leveraged loan buyer usually needs to obtain the borrower's or the sponsor's consent prior to acquiring the debt instrument. One potential solution would be to have parties be pre-authorized to purchase and sell a large amount of securities when they are given access to the private blockchain.

Exhibit 53: Settlement period could be reduced to 7 days from 21 today
Current vs. target settlement periods



Source: Markit Loan Settlement, LSTA (Loan Syndication and Trading Association).

Exhibit 54: Leveraged loan settlement: Key reasons for delay and potential solutions

	Timeline (Days)	Reasons for Delay	Potential Solutions / Best Practices
Trade Entry	1.3	Broker-dealers not linked to electronic settlement platform (ESP)	Broker-dealers should be linked to ESP
Allocation	2.7	Allocations not available on trade date - Limited buy-side capacity	Allocations entered into ESP within 1 day of trade entry
Signing of the Trade Confirm	5.5	Disputes on economic details and trade terms	Economic detail disagreements addressed by T+1
Signing of the Assignment Agreement	8.9	Signing of assignment agreement delayed until after trade confirm is executed	Assignment agreements should be signed with trade confirm
Approval to close	14.4	Buyers delay SDC until seller indicates ready to close, seller may be short	SDC checked as soon as assignment is signed
Agent Approval and Signature	19.4	Agents lack capacity to review every trade within 1 business day, 3 day delays commonplace	All trades approved within 1 business day. Capacity issues in agency units addressed by agent banks
			Borrower's consent sent out immediately when identified

Source: LSTA (Loan Syndication and Trading Association).

Reducing clearing and settlement times

Trade entry: This initial step currently takes 1.3 days for two main reasons: (1) there is no centrally available electronic settlement platform (ESP) that connects all brokers and (2) credit agreements are not submitted as soon as they become available. **A blockchain-based platform could act as a centrally available ESP.**

Allocation: This step usually takes 1.4 days, as allocations are not always available immediately on trade date. Moreover, the buy side is usually confronted with capacity issues, as allocations are entered manually into the ESP. Potential solutions include buy-side institutions having allocations available at T+0, and allocations being entered into the ESP within one day of the broker-dealer entering the trade. The blockchain does not offer a meaningful opportunity for a reduction in settlement times, as most of the delay appears to be due to buy-side capacity issues.

Signing of the trade confirmation: This step typically takes 2.8 days, as disputes regarding the economic details of the trade often arise. Potential solutions include addressing any disagreements about the economic details of the trade earlier in the process, and preferably by T+1. A meaningful hurdle for intermediaries in this process has been KYC and AML (know your customer and anti-money laundering) regulations, which require banks to run a thorough background check on their clients prior to transacting. **The advantage of a private blockchain would be that customers would have to be pre-authenticated to comply with KYC and AML legislation before they could transact.**

Signing of the assignment agreement (A&A): This step usually takes 3.4 days as transacting parties often submit additional assignment agreement questions and some institutions delay signing of the agreement until after the trade confirm is executed.

Approval to close: This stage currently requires 5.5 days, as the buyer waits to check off on the Settlement Date Coordination (SDC) until the seller indicates that it is ready to close, and may be managing its cash and delaying settlement until a seller is ready to close. blockchain could potentially help eliminate this step by automating the buyer check-off on

the SDC as soon as the assignment is signed and the buyer is ready to close, independent of the seller's situation.

Agent approval and signature: This step currently takes 5 days, mostly due to agents lacking the capacity to review trades in a timely manner and owing to substantial legal requirements, including FATCA. For this step, blockchain offers a meaningful opportunity for time reduction by potentially automating FATCA compliance checks.

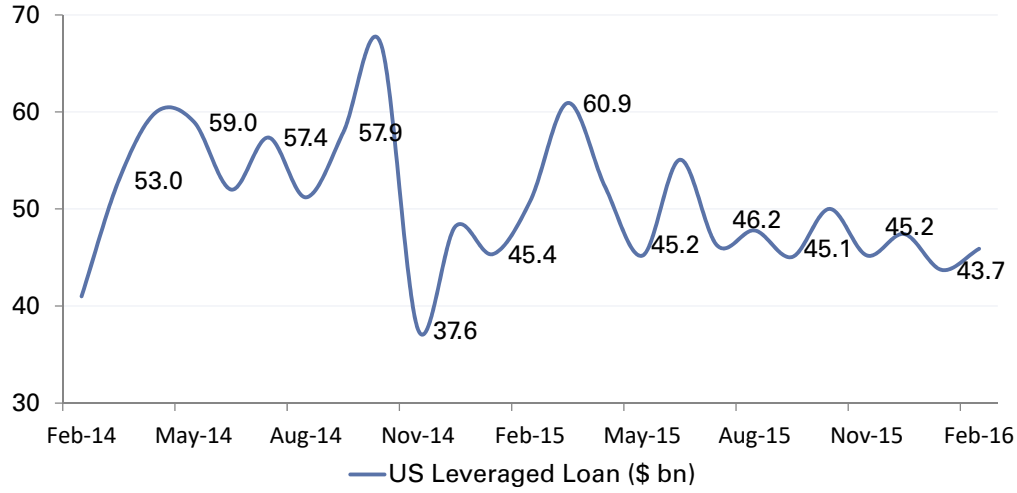
Post-trade reconciliation: Blockchain could also be particularly valuable for post-trade reconciliation. The post-trade process plays a fundamental role in distributing and duplicating the transaction information across all counterparts, attesting the transfer of the title of the asset. This process can be substantially accelerated through blockchain data synchronization throughout the entire network.

Quantifying the opportunity

We estimate that blockchain could help drive industry-wide cost savings of about $300mn annually for the industry, composed of ~$110mn in industry economic cost savings due to a reduction in balance sheet collateral requirements, ~$130mn in annual OpEx savings driven by process optimization and headcount reductions, and ~$50-$60mn in funding costs as the trade timeline is reduced.

Capital buffer economic costs: In order to quantify the economic cost under current collateral requirements, we derive the total estimated capital buffer for the leveraged loan industry based on the cumulative secondary value traded. **According to LSTA, approximately $590bn was traded in the secondary leveraged loans market in 2015.** We assume that (1) the bank would have to hold 1.3% capital buffer; (2) the risk weighted asset as defined by the regulator is notional*100% (or 1X); (3) the industry ROE target is 10%; and (4) capital risk is assumed on average 20% of the time. For example, using this methodology we estimate that for the month of February 2016, when ~$45.9bn was traded, the capital buffer requirement totaled ~$120mn and the economic cost for the industry was ~$12mn.

Exhibit 55: Secondary volume totaled $591bn in 2015
US leveraged loan monthly volume ($ bn)

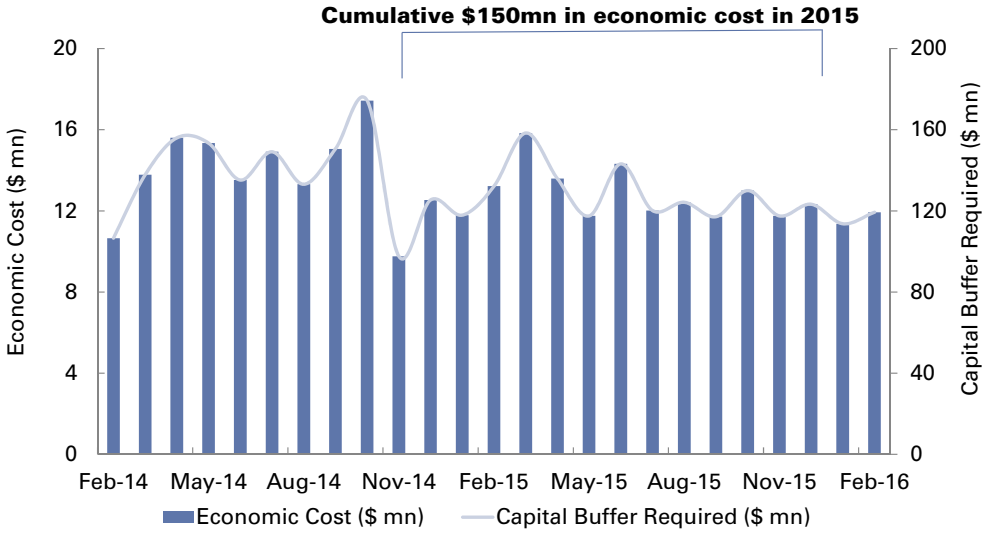


Source: LSTA.

Total 2015 industry economic cost reached ~$150mn: Based on our calculations, the total 2015 economic cost incurred by the industry due to the required balance sheet buffer was

~$150mn. This number is based on $591bn of trades in the leveraged loan secondary market during the year.

Exhibit 56: US leveraged loans – Industry capital buffer requirement and economic cost



Source: Goldman Sachs Global Investment Research.

Industry economic cost sensitivity analysis: We show below our sensitivity analysis to the number of days capital risk is held and the industry target ROE. **Our base case assumes an industry target ROE of 10%, which yields total industry economic cost of $150mn.** We use 10% for the purpose of our analysis, in line with data provided by the Federal Reserve Bank of St Louis, which shows that the ROE for the US banking industry has stabilized at ~9% over the past four years (since 1Q 2012). We find that a reduction in the settlement period could result in meaningful economic savings for the industry. **Holding the 10% ROE constant, every three-day reduction in settlement time (from ~21 days today) results in potential annual economic savings of ~$22mn.** This number reaches $31mn if we assume an ROE of 14%, which is more in line with industry profitability before the global financial crisis. Under our base case scenario of 10%, reducing the settlement time from 21 days to 6 days would result in ~$110mn in potential annual industry economic savings, as banks are able to deploy previously constrained capital.

Exhibit 57: Assuming target ROE of 10%, industry savings could reach ~$110mn if the settlement period falls to 6 days from 21 today

Industry Economic Savings vs. decrease in settlement time, holding ROE constant – US$ mn

2015		Industry Target ROE				
		6%	8%	10%	12%	14%
Settlement Days	21	-	-	-	-	-
	18	13	18	22	26	31
	15	26	35	44	53	62
	12	40	53	66	79	92
	9	53	70	88	105	123
	6	66	88	110	132	154

Source: Goldman Sachs Global Investment Research.

Reduction in funding costs: We estimate that the industry has $5.5bn in trades pending at any point in time, on which it incurs daily financing expenses. Assuming a 225bps interest rate (based on industry averages), this translates into $82.5mn in annual financing cost, which

would fall to ~$29mn if the settlement timeline is reduced from the current 20+ days to ~7 days, representing ~$55mn in savings for the industry.

Exhibit 58: We estimate a settlement timeline reduction could yield ~$55mn in savings
Annual funding cost analysis

Industry Annual Funding Cost	
Outstanding Trades ($ mn)	5,500
Interest rate (bps)	225
Average trade period (days)	20
Current Annual financing cost ($ mn)	82.5
7 day - average trade period scenario	
Annual financing costs ($ mn)	28.9
Annual financing savings ($ mn)	**53.6**

Source: Goldman Sachs Global Investment Research.

Reduction in systemic risk: Systemic risk refers to the risks that arise from interlinkages and interdependencies in the financial markets, where the failure of an institution can cause cascading failures among other financial institutions. A particular area of focus for regulators has been assets with low liquidity or long settlement cycles, such as leveraged loans. **Blockchain could offer a solution, as closed distributed ledgers help reduce counterparty credit and liquidity risk.**

Who could be disrupted?

Bank intermediaries: Blockchain would help reduce the need for bank intermediaries. A blockchain settlement platform offers a transparent and secured transaction ledger database, shared by all parties in a distributed private network. Blockchain technology is particularly interesting for this market because the notional outstanding values of these loans changes regularly as the debt is prepayable, making a transparent and easily accessible ledger particularly attractive.

Opex savings: Based on our analysis, we believe a 30% headcount reduction could be achieved by leveraging the blockchain process optimization, leading to ~$130mn in annual industry opex savings. This is based on an assumption of ~1,800 industry employees.

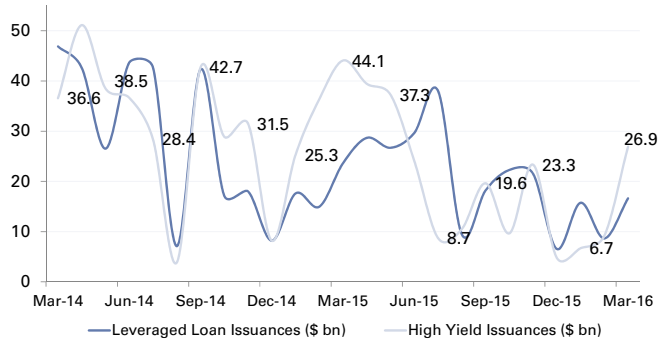
Challenges to adoption

Obtaining borrower's consent: We note one potential area of challenge is that a leveraged loan buyer usually needs to obtain the borrower's and/or the sponsor's consent prior to acquiring the debt instrument.

Internally connected Electronic Settlement Platform (ESP): Brokers have historically not connected to a shared electronic settlement platform. Ideally, such an ESP would feed into their internal systems. While this would certainly remove many of the roadblocks experienced by the industry, financial institutions could be reluctant to connect their internal and proprietary information to a completely transparent system that is available to all transacting parties.

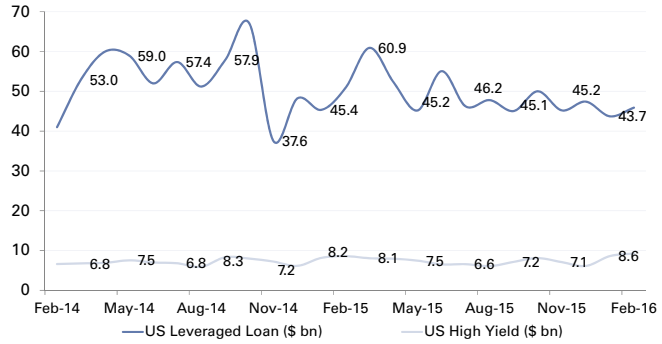
Tradeoff between leveraged loans and high-yield debt instruments: Leveraged loans are typically senior secured instruments and rank highest in the capital structure. We believe once the settlement period is reduced, the competition for capital between leveraged loans and high-yield debt instruments will increase as investors are able to more transparently determine whether they prefer a lower-yielding but less-risky loan (senior secured) or a higher-yielding but riskier bond. We show below the main characteristics of each market.

Exhibit 59: HY and loan issuances have fallen in 2016
US Leveraged Loan and High Yield Issuances – US$ bn



Source: Haver, LSTA.

Exhibit 60: Leveraged loan volumes remain relatively strong
US Loan and High Yield Monthly Volume– US$ bn



Source: Haver, LSTA, FINRA TRACE.

We note that the relatively high yields offered by leveraged loans and the seniority of the instruments have historically been the main reasons for the rise of the asset class. While it is not possible to quantify the exact impact that the settlement time reduction would have on the market volume and liquidity, we note that market liquidity has become increasingly important to the regulators. **Based on our conversations with various financial institutions, we believe that legislators would view such technological changes favorably and would encourage their development.**

Market liquidity

Market liquidity has become increasingly important for regulators and is seen as key to financial market stability. This could increase government support for technology (including blockchain) that would reduce settlement times. In September 2015, the SEC issued a proposed rule addressing open end mutual fund liquidity. Under the new legislation, each fund would prepare a liquidity risk management program that would:

- Assess, classify and monitor each portfolio asset's level of liquidity, based on the days it would take to convert the asset to cash; and
- Designate a minimum amount of portfolio liquidity.

Importantly, each fund would be required to make public the liquidity classification of each individual asset, as well as information about redemptions and swing pricing if applicable. The proposed rule would set the definition of "illiquid asset" as an asset that could not be sold within seven calendar days at approximately the value ascribed to it by the fund.

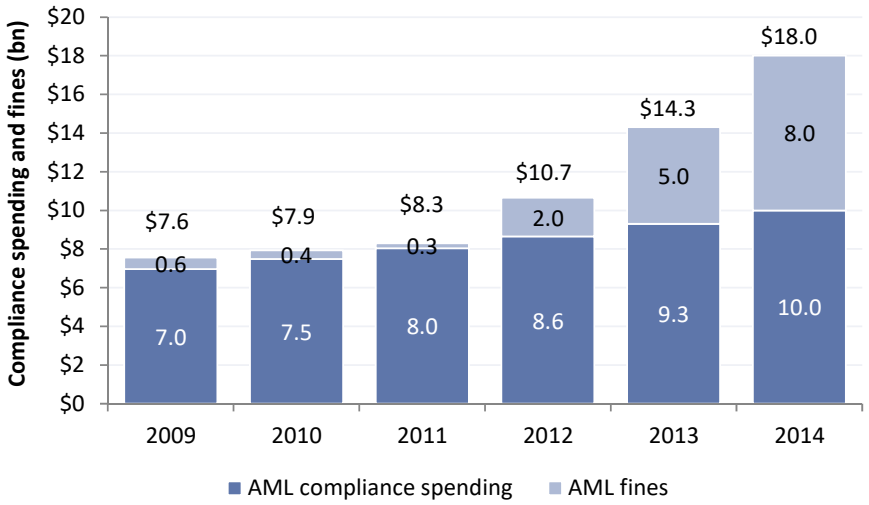
Case Study 7: AML and KYC Compliance

We believe blockchain has the opportunity to streamline and potentially transform anti-money laundering (AML) compliance procedures. By using a distributed database of payment transactions to better validate counterparty information, financial institutions could substantially reduce the false positive rate in transaction surveillance – which requires significant manual intervention today. In addition, over the long term we think a shared database of validated customer information could help streamline the KYC process that is involved in client onboarding. Together, we believe blockchain could drive between $3bn and $5bn in industry cost savings through reduction in personnel and in AML regulatory penalties.

What is the opportunity?

AML compliance spending totals ~$10bn annually. Money laundering (i.e., disguising the proceeds of illegal activity such as drug trafficking, financial fraud, etc. so as to appear to originate from legitimate sources or activities) is a serious problem in the international financial system. The World Bank estimates that the volume of money laundering is between $2.0tn and $3.5tn annually (3%-5% of global GDP). In an effort to combat this problem, regulators have instituted far-reaching guidelines for banks' in-house AML compliance programs. Still, third-party data suggests that less than ~1% of money laundering is detected, and banks have incurred significant regulatory penalties as a result. **Inclusive of regulatory penalties, total AML compliance costs borne by banks amount to ~$18bn annually** (AML fines alone totaled $8bn in 2014). We see an opportunity for blockchain to streamline AML monitoring procedures by "mutualizing" financial transaction information via a distributed ledger, which could drive meaningful industry cost savings in transaction surveillance and, potentially, in KYC onboarding.

Exhibit 61: AML compliance costs and regulatory fines continue to reach new highs
AML compliance spending + AML regulatory fines, 2009-2014 ($bn)



Source: Accenture, Celent.

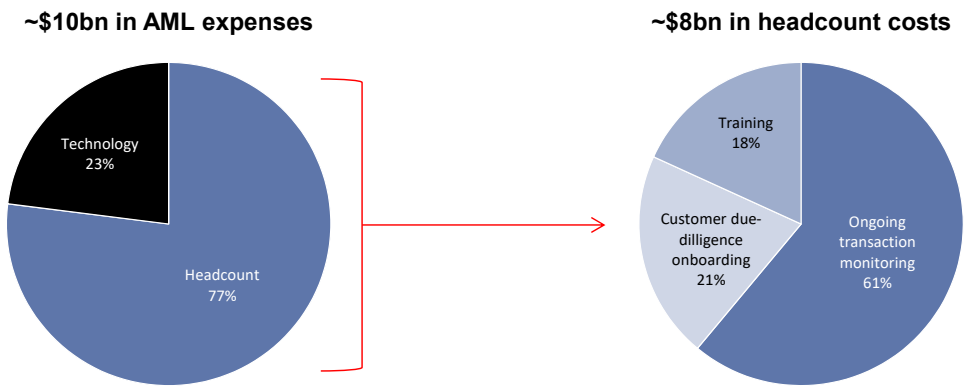
What are the pain points?

Implementation of AML requirements is highly labor intensive. In order to comply with evolving anti-money laundering regulations, financial institutions expend significant resources to develop and maintain their AML compliance programs. Although banks do automate many aspects of these procedures, the vast majority of AML budgets are dedicated to compliance personnel who manually scrutinize suspicious payment transactions and onboard new clients. We believe the existing banking system faces several structural problems that underscore the need for such manual oversight and the high cost structure involved in carrying out AML compliance programs:

- **Lack of data "mutualization" between banks leads to duplicate effort in client onboarding.** When a new client relationship is formed, financial institutions conduct a thorough customer due-diligence (CDD) process in accordance with "know your customer" (KYC) regulations. While the complexity of select retail and institutional account ownership structures requires manual review, KYC checks are often duplicative. In most jurisdictions, banks are required to independently vet prospective accounts even when the account has already been vetted by another bank. We estimate that proper KYC due diligence can cost $15k-$50k per client.
- **Lack of account codification leads to significant false-positive rates in transaction surveillance.** Although banks rely on transaction monitoring software to screen for suspicious behavior, our checks suggest that 2%-5% of all payment transactions are manually reviewed by compliance personnel to determine if money laundering has actually occurred. In such instances, false positive rates are ~99.9%. In the vast majority of cases, we believe this is not the result of deficiencies in monitoring software as much as it is due to poor transaction data quality (e.g., missing sender/receiver identification details). Whether or not money laundering has occurred, monitoring systems sound alerts when wire transfer information pertinent to the formation of an audit trail is either syntactically misrepresented or incomplete – and we believe this manual reconciliation process amounts to ~$6bn in costs borne by the industry.

As a result of these factors, financial institutions employ large numbers of people to carry out AML compliance programs. **Between onboarding, transaction monitoring, and recruitment personnel, we estimate that headcount costs represent nearly 80% of total AML budgets.** We believe much of these costs are a result of structural inefficiencies in the mutual flow of reliable information between financial counterparties, which requires the manual intervention of compliance personnel to facilitate the process.

Exhibit 62: AML operating costs largely consist of headcount costs
Illustrative breakdown of AML budget expense structure



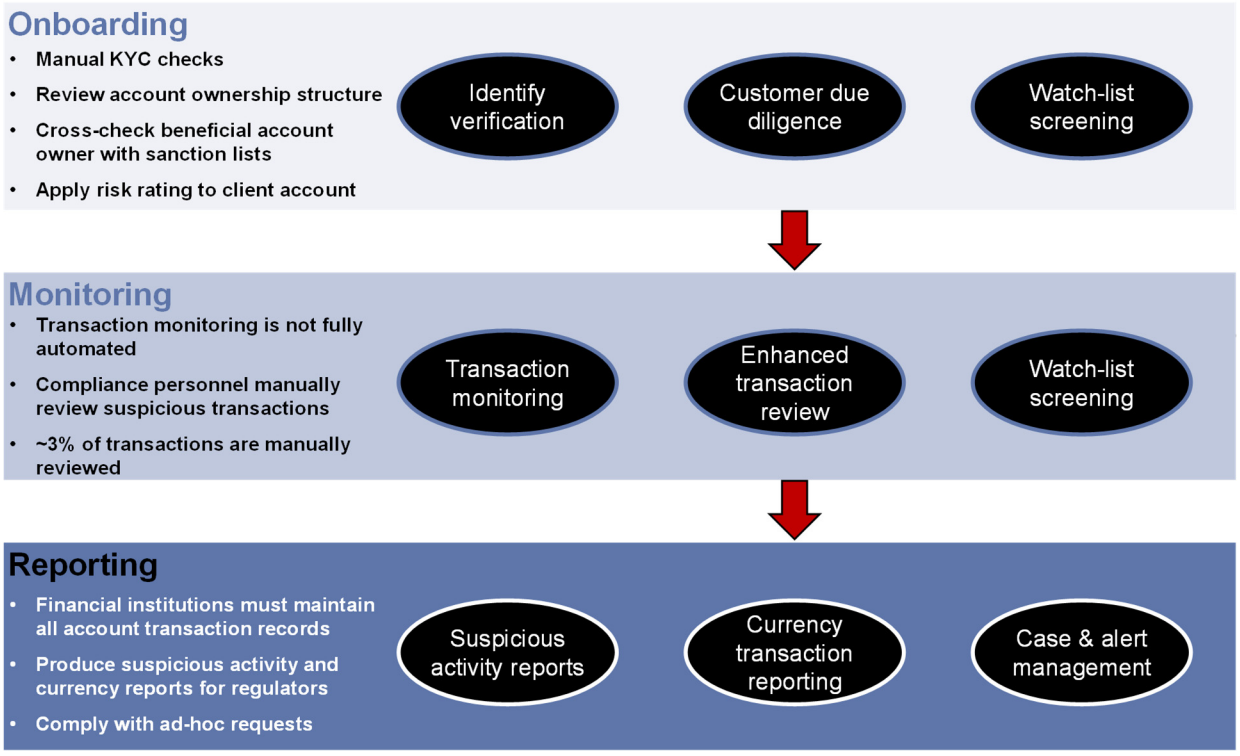
Source: Celent, Goldman Sachs Global Investment Research.

What is the current way of doing business?

Financial institutions implement AML procedures in several phases. Whether opening a bank account or moving money between accounts, financial intuitions employ AML procedures to mitigate counterparty risk in each step. We highlight the following phases to this process below:

- **Onboarding:** When a client seeks to open an account, banks conduct an exhaustive customer due-diligence process to verify customer identity and beneficial ownership of the account, and cross-check this data against sanctions lists. Given the complexities of select retail and institutional account ownership structures, KYC checks comprise a significant manual component.
- **Monitoring:** Once a client is on board, banks perform real-time and remedial transaction surveillance using advanced data analytics (typically provided by an external software vendor). We note that compliance personnel will manually review alerted transactions on a daily basis. Our checks suggest that 2%- 5% of all payment transactions are alerted, and these carry a ~99.9% false positive rate.
- **Reporting:** Financial institutions must maintain all necessary records on transactions, both domestic and international, as well as customer due-diligence information in order to comply swiftly with regulatory requests. Banks often prepare suspicious activity and currency transaction reports for authorities as well.

Exhibit 63: AML implementation procedures are highly manual
AML implementation phases



Source: Goldman Sachs Global Investment Research.

How does blockchain help?

Blockchain has the potential to improve structural pain points and ultimately streamline AML compliance. We believe new distributed database technology enabled by blockchain, in combination with enhanced policies and procedures, could significantly shore up the following pain points in today's system. **While we recognize that technology by itself is insufficient to address many of these structural challenges, we think systems could enhance procedures while enabling significant cost reductions:**

- **Secure codification of account details could enable greater transparency and efficiency in transaction surveillance.** By codifying the rules tied to completeness of account information (sending and receiving party details, legal entity information, etc.) that is part of every payment transaction, blockchain could improve the transparency of payment transactions and reduce the false positive rate. We believe this would reduce the labor overhead required to reconcile alert transactions with underlying money-laundering activity.
- **Distributed ledgers of present and past transactions would simplify recordkeeping and audit procedures.** Financial institutions could use a blockchain-based system to store an historical record of all transactions (including documents shared and compliance activities undertaken) on behalf of each client. Because all transactions tied to a particular client could be traced automatically, this record could be used to provide evidence that a bank has acted in accordance with AML demands, and enable it to quickly comply with regulatory requests.
- **Secure, distributed databases of client information shared between institutions could help reduce duplicative efforts in customer onboarding.** Each financial institution is required to conduct KYC checks for new accounts in order to validate the origin and associations of individuals, corporations, and sub-entities. In principle, financial institutions having a longstanding relationship with a client could potentially help "credentialize" that client with other institutions by providing supporting evidence of client associations through a secure, permissioned process facilitated by blockchain. While this would not completely eliminate the KYC burden for other financial institutions, it could potentially reduce the number of manual onboarding steps and reduce customer due-diligence costs.

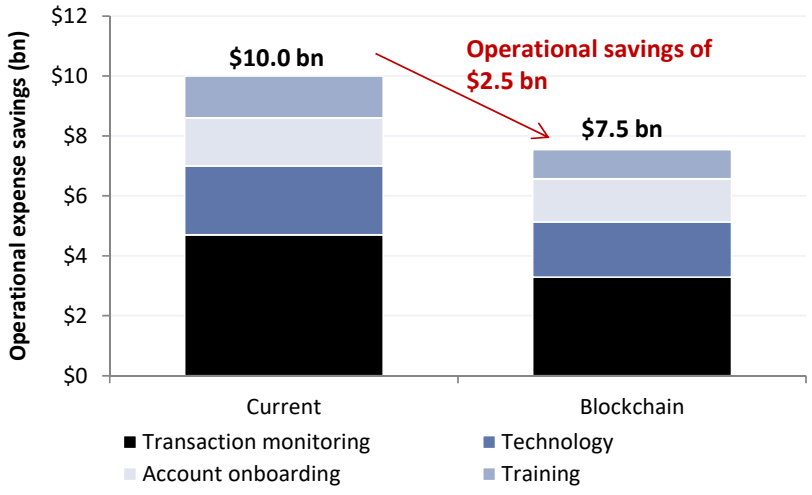
By streamlining these processes, blockchain could help reshape AML compliance implementation process. As a result of greater data integrity and accessibility, we believe the reliance on manual labor to conduct KYC checks and scrutinize suspected instances of laundering activity could be substantially reduced – thus allowing for potentially significant cost savings from reduced headcount. We would also expect blockchain to help improve counterparty risk as client information becomes more easily verifiable and systematic "misses" are reduced, potentially reducing monetary fines for financial institutions.

Quantifying the opportunity

We estimate that blockchain could drive substantial cost savings between $3bn and $5bn by reducing compliance personnel, technology expenses, and AML penalties. From an operational standpoint, we believe blockchain could introduce meaningful headcount efficiencies as manual aspects of transaction monitoring and onboarding procedures would be streamlined. While we do not believe blockchain by itself is a cure-all for inefficiencies in AML compliance, we believe the underlying technology – in conjunction with improved industry data policies and standards – could meaningfully increase the transparency of transactions. **In our base case, we estimate that blockchain could drive $2.5bn in operational cost savings** (headcount + technology). We break down our cost assumptions by function below:

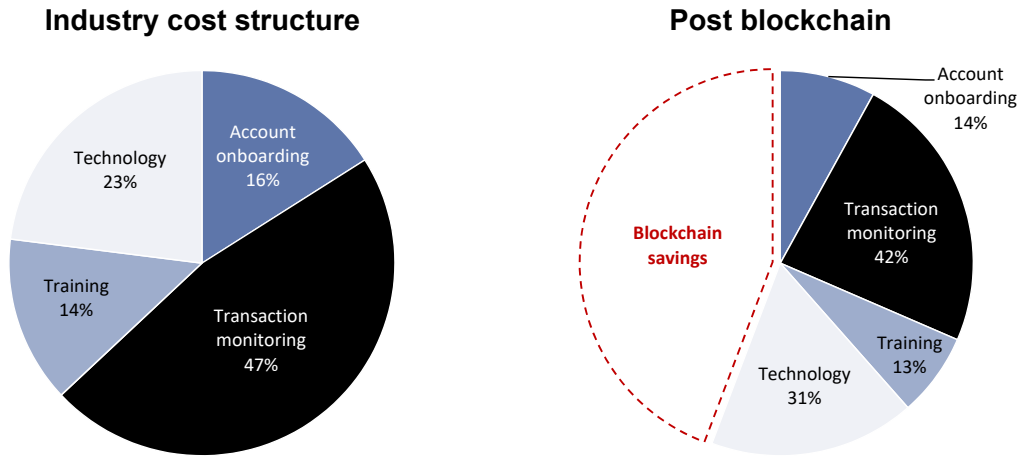
- **Customer onboarding: Modest cost savings with streamlined KYC effort.** We estimate blockchain could decrease customer onboarding headcount by 10%, introducing ~$160mn in cost savings. While a shared database of client information could eliminate duplicative aspects of KYC for select accounts with precedent banking relationships, we expect banks would still need to run customer diligence checks when the prospective account is a private company and/or individual setting up a bank account for the first time – or if the pre-existing customer data's authenticity is questionable (e.g., validated only by a single source). Importantly, blockchain would not remove banks' KYC liability, and thus we think banks will remain cautious when onboarding new accounts given AML penalties, despite improvements in customer data transparency and security.
- **Transaction monitoring: Meaningful efficiencies due to fewer "false positives" and less manual intervention.** We estimate blockchain could decrease transaction monitoring headcount by 30%, allowing for as much as $1.4bn in cost savings. We believe capturing and tracking customer information with blockchain in conjunction with unique client identifiers could introduce greater transparency to transaction surveillance. Since a large proportion of false positives are tied to transactions with incomplete information, we believe this could significantly reduce the number of false positives, thereby lowering the number of compliance personnel necessary to reconcile alerted transactions.
- **Training and technology: Significant cost savings resulting from less headcount and greater security.** We estimate blockchain could decrease training headcount by 30%, introducing ~$420mn in cost savings, tied solely to the reduction in headcount savings noted above. Over the long term, blockchain could lower technology expenses by 20% ($400mn-500mn in cost savings), given less reliance on proprietary systems.

Exhibit 64: We estimate blockchain could drive $2.5bn in operational cost savings
Estimated industry headcount operating expenses currently vs post-blockchain ($bn)



Source: Celent, Goldman Sachs Global Investment Research.

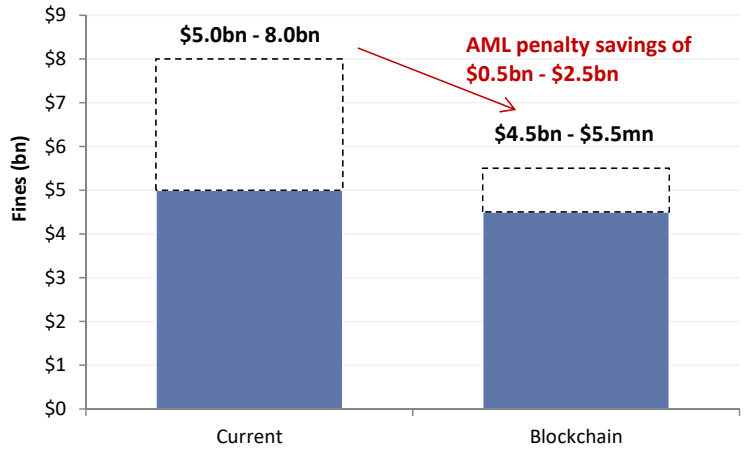
Exhibit 65: Labor-intensive AML implementation expenses could see significant reduction
Estimated industry operating expense composition currently vs post-blockchain



Source: Goldman Sachs Global Investment Research.

Wildcard: Higher capture rates could potentially reduce AML regulatory fines. Banks incurred approximately $8bn in AML regulatory fines in 2014, according to an Accenture report. While it is highly unlikely that money-laundering risk would be fully eliminated if payment transactions were linked to blockchain, we would expect that "capture rates" would improve in the presence of more-effective systems with more extensive audit and tracing capability. In addition to specific instances of money laundering violations, programmatic deficiencies associated with transaction monitoring procedures have driven significant penalties in recent years – and we think these systematic fines could probably be substantially reduced with better systems in place. **In our base case we estimate that AML penalties could be reduced by 10% to 40% - generating cost savings of $0.5 - $2.5bn annually.**

Exhibit 66: Blockchain could drive between $0.5 - $2.5bn in AML penalty savings annually
Estimated AML penalties currently and post-blockchain



Source: Accenture, Goldman Sachs Global Investment Research.

**Numbers may not sum due to rounding.*

Exhibit 67: In our base scenario, blockchain could drive $3.0bn - $5.0bn in total cost savings
Cost savings by operating expense line item

	Current		Blockchain		
Operating Expenses	Absolute cost (bn)	% of total	Absolute cost (bn)	% of Opex	Savings (bn)
Account onboarding	$1.6	10%	$1.4	13%	**$0.2**
Transaction monitoring	$4.7	28%	$3.3	29%	**$1.4**
Training	$1.4	8%	$1.0	9%	**$0.4**
Technology	$2.3	14%	$1.8	16%	**$0.5**
AML fines	$5.0 - $8.0	39%	$2.5 - $5.0	33%	**$0.5 - $2.5**
Total	**$15.0 - $18.0**		**$10.0 - $12.5**		**$3.0 - $5.0**

Source: Goldman Sachs Global Investment Research.

Who could be disrupted?

We believe blockchain could potentially have the most impact on AML software providers. We note that most financial institutions, particularly smaller-sized banks, rely on externally provided AML software solutions to screen for suspicious transaction activity and sanction-list filtering.

Challenges to adoption

Critical mass of counterparty information. We believe a critical mass of information is needed in order for data to be commercially reliable. For example, in cases where there is a scarcity of validated counterparty information (e.g., validated only by a single source), we expect banks would still need to run their own KYC checks and/or transaction surveillance to independently corroborate client information.

Regulatory reform. Regulatory reform that supports blockchain-based applications will be needed before financial institutions are able to embrace the technology. While blockchain will likely not remove banks' AML liability, blockchain-based distributed ledgers will need to be legitimized by governing bodies (i.e., fiat currency) in order for banks to comfortably rely on them as a source of counterparty information.

Infrastructure development. The development of blockchain-based infrastructure that operates in conjunction with existing industry standards is needed for commercial adoption. For example, we note that wire transfer information (e.g., ABA routing numbers) will need to be tied to a blockchain index to improve the security of money movement transactions. As such, we believe considerable investment is needed to implement requisite infrastructure.

Disclosure Appendix

Reg AC

We, James Schneider, Ph.D., Alexander Blostein, CFA, Brian Lee, CFA, Steven Kent, CFA, Ingrid Groer, CFA, Eric Beardsley, CFA, Conor Fitzgerald, Michael Lapides, Robert D. Boroujerdi, Jordan Fox, Pierre Safa, Grayson Barnard, CFA, Hank Elder and Lara Fourman, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

I, Brian Rooney, hereby certify that all of the views expressed in this report accurately reflect my personal views, which have not been influenced by considerations of the firm's business or client relationships.

Unless otherwise stated, the individuals listed on the cover page of this report are analysts in Goldman Sachs' Global Investment Research division.

Investment Profile

The Goldman Sachs Investment Profile provides investment context for a security by comparing key attributes of that security to its peer group and market. The four key attributes depicted are: growth, returns, multiple and volatility. Growth, returns and multiple are indexed based on composites of several methodologies to determine the stocks percentile ranking within the region's coverage universe.

The precise calculation of each metric may vary depending on the fiscal year, industry and region but the standard approach is as follows:

Growth is a composite of next year's estimate over current year's estimate, e.g. EPS, EBITDA, Revenue. **Return** is a year one prospective aggregate of various return on capital measures, e.g. CROCI, ROACE, and ROE. **Multiple** is a composite of one-year forward valuation ratios, e.g. P/E, dividend yield, EV/FCF, EV/EBITDA, EV/DACF, Price/Book. **Volatility** is measured as trailing twelve-month volatility adjusted for dividends.

Quantum

Quantum is Goldman Sachs' proprietary database providing access to detailed financial statement histories, forecasts and ratios. It can be used for in-depth analysis of a single company, or to make comparisons between companies in different sectors and markets.

GS SUSTAIN

GS SUSTAIN is a global investment strategy aimed at long-term, long-only performance with a low turnover of ideas. The GS SUSTAIN focus list includes leaders our analysis shows to be well positioned to deliver long term outperformance through sustained competitive advantage and superior returns on capital relative to their global industry peers. Leaders are identified based on quantifiable analysis of three aspects of corporate performance: cash return on cash invested, industry positioning and management quality (the effectiveness of companies' management of the environmental, social and governance issues facing their industry).

Disclosures

Coverage group(s) of stocks by primary analyst(s)

James Schneider, Ph.D.: America-ATM/POS and Self-Service, America-IT Consulting and Outsourcing, America-Transaction Processors. Alexander Blostein, CFA: America-Alternative Asset Managers, America-Market Structure, America-Traditional Asset Managers, America-Trust Banks. Brian Lee, CFA: America-Clean Energy, America-Solar Energy. Steven Kent, CFA: America-Gaming, America-Gaming Technology, America-Leisure, America-Lodging. Ingrid Groer, CFA: Australia-Diversified Financials. Eric Beardsley, CFA: America-Specialty Finance. Conor Fitzgerald: America-Brokers. Michael Lapides: America-Diversified Utilities, America-Independent Power Producers, America-Regulated Utilities.

America-ATM/POS and Self-Service: CPI Card Group, CPI Card Group, VeriFone Systems Inc..

America-Alternative Asset Managers: Apollo Global Management LLC, Ares Management LP, Blackstone Group, Carlyle Group LP, KKR & Co., Oaktree Capital Group, Och-Ziff Capital Management Group.

America-Brokers: Charles Schwab Corp., E*TRADE Financial Corp., Interactive Brokers Group, LPL Financial Holdings, TD Ameritrade Holding.

America-Clean Energy: Acuity Brands Inc., Cree Inc., Silver Spring Networks Inc., TerraVia Holdings, Universal Display Corp., Veeco Instruments Inc..

America-Diversified Utilities: Centerpoint Energy Inc., Dominion Resources Inc., Entergy Corp., Exelon Corp., FirstEnergy Corp., NextEra Energy Inc., Public Service Enterprise Group, Sempra Energy.

America-Gaming: Boyd Gaming Corp., Gaming and Leisure Properties Inc., Las Vegas Sands Corp., MGM Resorts International, Penn National Gaming Inc., Pinnacle Entertainment Inc., Red Rock Resorts Inc., Wynn Resorts Ltd..

America-Gaming Technology: International Game Technology Plc, Scientific Games Corp..

America-IT Consulting and Outsourcing: Accenture Plc, Black Knight Financial Services Inc., CGI Group, CGI Group, Cognizant Technology Solutions, Computer Sciences Corp., Fidelity National Information Services, Fiserv Inc., International Business Machines, Sabre Corp., West Corp..

America-Independent Power Producers: Calpine Corp., Dynegy Inc., NextEra Energy Partners, NRG Energy Inc., NRG Yield Inc..

America-Leisure: Carnival Corp., ClubCorp Holdings, Intrawest Resorts Holdings, Norwegian Cruise Line Holdings, Royal Caribbean Cruises Ltd., Vail Resorts Inc..

America-Lodging: Choice Hotels International Inc., Diamond Resorts International Inc., DiamondRock Hospitality Co., Extended Stay America Inc., Hilton Worldwide Holdings, Host Hotels & Resorts Inc., Hyatt Hotels Corp., Interval Leisure Group, La Quinta Holdings, LaSalle Hotel Properties, Marriott International, Marriott Vacations Worldwide, Starwood Hotels & Resorts, Wyndham Worldwide Corp..

America-Market Structure: BATS Global Markets Inc., CBOE Holdings, CME Group, IntercontinentalExchange Inc., Nasdaq, Inc., Virtu Financial Inc..

America-Regulated Utilities: Ameren Corp., American Electric Power, American Water Works, Consolidated Edison Inc., Duke Energy Corp., Edison International, Eversource Energy, Great Plains Energy Inc., PG&E Corp., Pinnacle West Capital Corp., Portland General Electric Co., PPL Corp., SCANA Corp., Southern Co., WEC Energy Group Inc., Westar Energy Inc..

America-Solar Energy: 8point3 Energy Partners, First Solar Inc., SolarCity Corp., SolarEdge Technologies Inc., SunPower Corp., Sunrun Inc., TerraForm Global Inc., TerraForm Power Inc., Vivint Solar Inc..

America-Specialty Finance: Ally Financial Inc., American Capital Agency Corp., Annaly Capital Management Inc., CIT Group, Colony Capital Inc., Essent Group, Fidelity National Financial Inc., First American Financial Corp., MGIC Investment Corp., Navient Corp., PennyMac Financial Services Inc., Radian Group, Santander Consumer USA Holdings, SLM Corp., Starwood Property Trust Inc., Two Harbors Investment Corp..

America-Traditional Asset Managers: Affiliated Managers Group, AllianceBernstein Holding, Ameriprise Financial Inc., Artisan Partners Asset, BlackRock Inc., Franklin Resources Inc., Invesco Ltd., Janus Capital Group, T. Rowe Price Group, Virtus Investment Partners, WisdomTree Investments Inc..

America-Transaction Processors: Automatic Data Processing Inc., Blackhawk Network Holdings, Evertec Inc., First Data Corp., FleetCor Technologies Inc., Global Payments Inc., MasterCard Inc., MoneyGram International Inc., Paychex Inc., Square Inc., Total System Services Inc., Vantiv Inc., Visa Inc., Western Union Co., WEX Inc..

America-Trust Banks: Bank of New York Mellon Corp., Northern Trust Corp., State Street Corp..

Australia-Diversified Financials: AMP, ASX Ltd., BT Investment Management Ltd., Challenger Ltd., Computershare, Henderson Group, IOOF Holdings, Perpetual Ltd..

Company-specific regulatory disclosures

Compendium report: please see disclosures at http://www.gs.com/research/hedge.html. Disclosures applicable to the companies included in this compendium can be found in the latest relevant published research

Distribution of ratings/investment banking relationships

Goldman Sachs Investment Research global Equity coverage universe

	Rating Distribution			Investment Banking Relationships		
	Buy	Hold	Sell	Buy	Hold	Sell
Global	32%	53%	15%	65%	58%	51%

As of April 1, 2016, Goldman Sachs Global Investment Research had investment ratings on 3,029 equity securities. Goldman Sachs assigns stocks as Buys and Sells on various regional Investment Lists; stocks not so assigned are deemed Neutral. Such assignments equate to Buy, Hold and Sell for the purposes of the above disclosure required by the FINRA Rules. See 'Ratings, Coverage groups and views and related definitions' below. The Investment Banking Relationships chart reflects the percentage of subject companies within each rating category for whom Goldman Sachs has provided investment banking services within the previous twelve months.

Price target and rating history chart(s)

Compendium report: please see disclosures at http://www.gs.com/research/hedge.html. Disclosures applicable to the companies included in this compendium can be found in the latest relevant published research

Regulatory disclosures

Disclosures required by United States laws and regulations

See company-specific regulatory disclosures above for any of the following disclosures required as to companies referred to in this report: manager or co-manager in a pending transaction; 1% or other ownership; compensation for certain services; types of client relationships; managed/co-managed public offerings in prior periods; directorships; for equity securities, market making and/or specialist role. Goldman Sachs trades or may trade as a principal in debt securities (or in related derivatives) of issuers discussed in this report.

The following are additional required disclosures: **Ownership and material conflicts of interest:** Goldman Sachs policy prohibits its analysts, professionals reporting to analysts and members of their households from owning securities of any company in the analyst's area of coverage. **Analyst compensation:** Analysts are paid in part based on the profitability of Goldman Sachs, which includes investment banking revenues. **Analyst as officer or director:** Goldman Sachs policy prohibits its analysts, persons reporting to analysts or members of their households from serving as an officer, director, advisory board member or employee of any company in the analyst's area of coverage. **Non-U.S. Analysts:** Non-U.S. analysts may not be associated persons of Goldman, Sachs & Co. and therefore may not be subject to FINRA Rule 2241 or FINRA Rule 2242 restrictions on communications with subject company, public appearances and trading securities held by the analysts.

Distribution of ratings: See the distribution of ratings disclosure above. **Price chart:** See the price chart, with changes of ratings and price targets in prior periods, above, or, if electronic format or if with respect to multiple companies which are the subject of this report, on the Goldman Sachs website at http://www.gs.com/research/hedge.html.

Additional disclosures required under the laws and regulations of jurisdictions other than the United States

The following disclosures are those required by the jurisdiction indicated, except to the extent already made above pursuant to United States laws and regulations. **Australia:** Goldman Sachs Australia Pty Ltd and its affiliates are not authorised deposit-taking institutions (as that term is defined in the Banking Act 1959 (Cth)) in Australia and do not provide banking services, nor carry on a banking business, in Australia. This research, and any access to it, is intended only for "wholesale clients" within the meaning of the Australian Corporations Act, unless otherwise agreed by Goldman Sachs. In producing research reports, members of the Global Investment Research Division of Goldman Sachs Australia may attend site visits and other meetings hosted by the issuers the subject of its research reports. In some instances the costs of such site visits or meetings may be met in part or in whole by the issuers concerned if Goldman Sachs Australia considers it is appropriate and reasonable in the specific circumstances relating to the site visit or meeting. **Brazil:** Disclosure information in relation to CVM Instruction 483 is available at http://www.gs.com/worldwide/brazil/area/gir/index.html. Where applicable, the Brazil-registered analyst primarily responsible for the content of this research report, as defined in Article 16 of CVM Instruction 483, is the first author named at the beginning of this report, unless indicated otherwise at the end of the text. **Canada:** Goldman Sachs Canada Inc. is an affiliate of The Goldman Sachs Group Inc. and therefore is included in the company specific disclosures relating to Goldman Sachs (as defined above). Goldman Sachs Canada Inc. has approved of, and agreed to take responsibility for, this research report in Canada if and to the extent that Goldman Sachs Canada Inc. disseminates this research report to its clients. **Hong Kong:** Further information on the securities of covered companies referred to in this research may be obtained on request from Goldman Sachs (Asia) L.L.C. **India:** Further information on the subject company or companies referred to in this research may be obtained from Goldman Sachs (India) Securities Private Limited, Research Analyst - SEBI Registration Number INH000001493, 951-A, Rational House, Appasaheb Marathe Marg, Prabhadevi, Mumbai 400 025, India, Corporate Identity Number U74140MH2006FTC160634, Phone +91 22 6616 9000, Fax +91 22 6616 9001. Goldman Sachs may beneficially own 1% or more of the securities (as such term is defined in clause 2 (h) the Indian Securities Contracts (Regulation) Act, 1956) of the subject company or companies referred to in this research report. **Japan:** See below. **Korea:** Further information on the subject

company or companies referred to in this research may be obtained from Goldman Sachs (Asia) L.L.C., Seoul Branch. **New Zealand:** Goldman Sachs New Zealand Limited and its affiliates are neither "registered banks" nor "deposit takers" (as defined in the Reserve Bank of New Zealand Act 1989) in New Zealand. This research, and any access to it, is intended for "wholesale clients" (as defined in the Financial Advisers Act 2008) unless otherwise agreed by Goldman Sachs. **Russia:** Research reports distributed in the Russian Federation are not advertising as defined in the Russian legislation, but are information and analysis not having product promotion as their main purpose and do not provide appraisal within the meaning of the Russian legislation on appraisal activity. **Singapore:** Further information on the covered companies referred to in this research may be obtained from Goldman Sachs (Singapore) Pte. (Company Number: 198602165W). **Taiwan:** This material is for reference only and must not be reprinted without permission. Investors should carefully consider their own investment risk. Investment results are the responsibility of the individual investor. **United Kingdom:** Persons who would be categorized as retail clients in the United Kingdom, as such term is defined in the rules of the Financial Conduct Authority, should read this research in conjunction with prior Goldman Sachs research on the covered companies referred to herein and should refer to the risk warnings that have been sent to them by Goldman Sachs International. A copy of these risks warnings, and a glossary of certain financial terms used in this report, are available from Goldman Sachs International on request.

European Union: Disclosure information in relation to Article 4 (1) (d) and Article 6 (2) of the European Commission Directive 2003/125/EC is available at http://www.gs.com/disclosures/europeanpolicy.html which states the European Policy for Managing Conflicts of Interest in Connection with Investment Research.

Japan: Goldman Sachs Japan Co., Ltd. is a Financial Instrument Dealer registered with the Kanto Financial Bureau under registration number Kinsho 69, and a member of Japan Securities Dealers Association, Financial Futures Association of Japan and Type II Financial Instruments Firms Association. Sales and purchase of equities are subject to commission pre-determined with clients plus consumption tax. See company-specific disclosures as to any applicable disclosures required by Japanese stock exchanges, the Japanese Securities Dealers Association or the Japanese Securities Finance Company.

Ratings, coverage groups and views and related definitions

Buy (B), Neutral (N), Sell (S) -Analysts recommend stocks as Buys or Sells for inclusion on various regional Investment Lists. Being assigned a Buy or Sell on an Investment List is determined by a stock's return potential relative to its coverage group as described below. Any stock not assigned as a Buy or a Sell on an Investment List is deemed Neutral. Each regional Investment Review Committee manages various regional Investment Lists to a global guideline of 25%-35% of stocks as Buy and 10%-15% of stocks as Sell; however, the distribution of Buys and Sells in any particular coverage group may vary as determined by the regional Investment Review Committee. Regional Conviction Buy and Sell lists represent investment recommendations focused on either the size of the potential return or the likelihood of the realization of the return.

Return potential represents the price differential between the current share price and the price target expected during the time horizon associated with the price target. Price targets are required for all covered stocks. The return potential, price target and associated time horizon are stated in each report adding or reiterating an Investment List membership.

Coverage groups and views: A list of all stocks in each coverage group is available by primary analyst, stock and coverage group at http://www.gs.com/research/hedge.html. The analyst assigns one of the following coverage views which represents the analyst's investment outlook on the coverage group relative to the group's historical fundamentals and/or valuation. **Attractive (A).** The investment outlook over the following 12 months is favorable relative to the coverage group's historical fundamentals and/or valuation. **Neutral (N).** The investment outlook over the following 12 months is neutral relative to the coverage group's historical fundamentals and/or valuation. **Cautious (C).** The investment outlook over the following 12 months is unfavorable relative to the coverage group's historical fundamentals and/or valuation.

Not Rated (NR). The investment rating and target price have been removed pursuant to Goldman Sachs policy when Goldman Sachs is acting in an advisory capacity in a merger or strategic transaction involving this company and in certain other circumstances. **Rating Suspended (RS).** Goldman Sachs Research has suspended the investment rating and price target for this stock, because there is not a sufficient fundamental basis for determining, or there are legal, regulatory or policy constraints around publishing, an investment rating or target. The previous investment rating and price target, if any, are no longer in effect for this stock and should not be relied upon. **Coverage Suspended (CS).** Goldman Sachs has suspended coverage of this company. **Not Covered (NC).** Goldman Sachs does not cover this company. **Not Available or Not Applicable (NA).** The information is not available for display or is not applicable. **Not Meaningful (NM).** The information is not meaningful and is therefore excluded.

Global product; distributing entities

The Global Investment Research Division of Goldman Sachs produces and distributes research products for clients of Goldman Sachs on a global basis. Analysts based in Goldman Sachs offices around the world produce equity research on industries and companies, and research on macroeconomics, currencies, commodities and portfolio strategy. This research is disseminated in Australia by Goldman Sachs Australia Pty Ltd (ABN 21 006 797 897); in Brazil by Goldman Sachs do Brasil Corretora de Títulos e Valores Mobiliários S.A.; in Canada by either Goldman Sachs Canada Inc. or Goldman, Sachs & Co.; in Hong Kong by Goldman Sachs (Asia) L.L.C.; in India by Goldman Sachs (India) Securities Private Ltd.; in Japan by Goldman Sachs Japan Co., Ltd.; in the Republic of Korea by Goldman Sachs (Asia) L.L.C., Seoul Branch; in New Zealand by Goldman Sachs New Zealand Limited; in Russia by OOO Goldman Sachs; in Singapore by Goldman Sachs (Singapore) Pte. (Company Number: 198602165W); and in the United States of America by Goldman, Sachs & Co. Goldman Sachs International has approved this research in connection with its distribution in the United Kingdom and European Union.

European Union: Goldman Sachs International authorised by the Prudential Regulation Authority and regulated by the Financial Conduct Authority and the Prudential Regulation Authority, has approved this research in connection with its distribution in the European Union and United Kingdom; Goldman Sachs AG and Goldman Sachs International Zweigniederlassung Frankfurt, regulated by the Bundesanstalt für Finanzdienstleistungsaufsicht, may also distribute research in Germany.

General disclosures

This research is for our clients only. Other than disclosures relating to Goldman Sachs, this research is based on current public information that we consider reliable, but we do not represent it is accurate or complete, and it should not be relied on as such. The information, opinions, estimates and forecasts contained herein are as of the date hereof and are subject to change without prior notification. We seek to update our research as appropriate, but various regulations may prevent us from doing so. Other than certain industry reports published on a periodic basis, the large majority of reports are published at irregular intervals as appropriate in the analyst's judgment.

Goldman Sachs conducts a global full-service, integrated investment banking, investment management, and brokerage business. We have investment banking and other business relationships with a substantial percentage of the companies covered by our Global Investment Research Division. Goldman, Sachs & Co., the United States broker dealer, is a member of SIPC (http://www.sipc.org).

Our salespeople, traders, and other professionals may provide oral or written market commentary or trading strategies to our clients and principal trading desks that reflect opinions that are contrary to the opinions expressed in this research. Our asset management area, principal trading desks and investing businesses may make investment decisions that are inconsistent with the recommendations or views expressed in this research.

The analysts named in this report may have from time to time discussed with our clients, including Goldman Sachs salespersons and traders, or may discuss in this report, trading strategies that reference catalysts or events that may have a near-term impact on the market price of the equity securities discussed in this report, which impact may be directionally counter to the analyst's published price target expectations for such stocks. Any such trading strategies are distinct from and do not affect the analyst's fundamental equity rating for such stocks, which rating reflects a stock's return potential relative to its coverage group as described herein.

We and our affiliates, officers, directors, and employees, excluding equity and credit analysts, will from time to time have long or short positions in, act as principal in, and buy or sell, the securities or derivatives, if any, referred to in this research.

The views attributed to third party presenters at Goldman Sachs arranged conferences, including individuals from other parts of Goldman Sachs, do not necessarily reflect those of Global Investment Research and are not an official view of Goldman Sachs.

Any third party referenced herein, including any salespeople, traders and other professionals or members of their household, may have positions in the products mentioned that are inconsistent with the views expressed by analysts named in this report.

This research is not an offer to sell or the solicitation of an offer to buy any security in any jurisdiction where such an offer or solicitation would be illegal. It does not constitute a personal recommendation or take into account the particular investment objectives, financial situations, or needs of individual clients. Clients should consider whether any advice or recommendation in this research is suitable for their particular circumstances and, if appropriate, seek professional advice, including tax advice. The price and value of investments referred to in this research and the income from them may fluctuate. Past performance is not a guide to future performance, future returns are not guaranteed, and a loss of original capital may occur. Fluctuations in exchange rates could have adverse effects on the value or price of, or income derived from, certain investments.

Certain transactions, including those involving futures, options, and other derivatives, give rise to substantial risk and are not suitable for all investors. Investors should review current options disclosure documents which are available from Goldman Sachs sales representatives or at http://www.theocc.com/about/publications/character-risks.jsp. Transaction costs may be significant in option strategies calling for multiple purchase and sales of options such as spreads. Supporting documentation will be supplied upon request.

All research reports are disseminated and available to all clients simultaneously through electronic publication to our internal client websites. Not all research content is redistributed to our clients or available to third-party aggregators, nor is Goldman Sachs responsible for the redistribution of our research by third party aggregators. For research, models or other data available on a particular security, please contact your sales representative or go to http://360.gs.com.

Disclosure information is also available at http://www.gs.com/research/hedge.html or from Research Compliance, 200 West Street, New York, NY 10282.