



Brief

Infrastructure Debt: Alternative Credit to Finance the Future

Simon Beckman
Philip Clements, CFA
Matthieu Le Bret
Alfonso Ricciardelli, CFA



CFA Institute
Research
Foundation

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ISBN: 978-1-952927-72-0

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INFRASTRUCTURE DEBT: ALTERNATIVE CREDIT TO FINANCE THE FUTURE

Simon Beckman
Senior Vice President, Energy Division
DNB Bank ASA

Philip Clements, CFA
CEO, Finspector

Matthieu Le Bret
Managing Director and Global Head, Investment Solutions
NORD/LB

Alfonso Ricciardelli, CFA
Content and Research Lead, Endowus

Introduction

Infrastructure debt was once a niche asset class, confined to a limited group of specialized lenders and project sponsors. But more recently, it has attracted investor attention as it grew into a critical financing channel for some of the world's most urgent and capital-intensive needs: clean energy transition, digitalization (especially data centers), and resilient public services.

What makes infrastructure debt's profile stand out is the relative stability of its underlying fundamentals. This asset class is built around essential services and tangible, long-duration assets, offering investors potential for fixed and predictable cash flows, as well as historically low default rates. Yet beneath that surface of stability, infrastructure debt is undergoing a transformation.

Over the last seven years, the global private infrastructure investment market has more than doubled, and annual transaction volume is now worth more than USD1 trillion. The majority of this growth (close to 75%) has taken place in the United States and Europe,¹ where three macroeconomic forces are converging to reshape the sector:

- A wave of renewed public spending, as Western governments respond to economic stagnation, geopolitical tensions, and climate imperatives with stimulus plans focused

¹See Hans Vrensen, CFA, and Irène Fossé, "Private Infra Lenders Target Solid Margins at Modest Risk," AEW (July 2024), www.aew.com/research/private-infra-lenders-target-solid-margins-at-modest-risk. The Asia-Pacific region is lagging, despite a USD13.8 trillion infrastructure investment gap and recent steps to open to foreign institutional players. See Angus Davidson, "Infrastructure Debt: Unlocking Asia's Growth," Natixis Investment Managers (29 September 2025), www.im.natixis.com/en-intl/insights/private-assets/2025/infrastructure-debt-unlocking-asias-growth.

on infrastructure, such as the EU's EUR800 billion NextGenerationEU fund,² as well as the surviving parts of the Inflation Reduction Act and the more recent push for data center construction in the United States³

- The green energy transition, which is accelerating demand for financing in renewables, power grids, and climate-resilient infrastructure—even amid political backlash against environmental, social, and governance (ESG) frameworks
- The rise of AI and digital infrastructure, which is driving exponential investment in data centers, telecommunications networks, and energy generation

These trends are also “creating” new return profiles and risk factors. Traditionally, infrastructure debt has appealed to investors for its defensive qualities: typically strong covenants, low correlation with public equity markets, and desirable exposure to creditworthy counterparties. But with increasing competition for opportunities, new types of borrowers, and structural innovations in financing, investors now face a far more complex landscape than before.

This brief explores how infrastructure debt is evolving as an asset class, from its core definitions and risk-return profile to its growing diversity across sectors, regions, and strategies. We examine key instrument types (e.g., project finance versus corporate infrastructure debt), the role of government support mechanisms, and the implications of emerging structural trends, such as net-zero mandates and AI-driven demand.

The brief begins with an overview of infrastructure debt's history, including types of financing and investors. A deep dive into the diverse set of infrastructure investment assets follows. We then zero in on clean energy, drawing some conclusions from the Nordic experience.

As infrastructure debt enters a new era, understanding its nuances becomes more important than ever—for allocators, policymakers, and investors alike.

Evolution of Infrastructure Debt Financing

Infrastructure debt has become a vital tool to finance capital-intensive assets across multiple sectors. Although this asset class historically has been dominated by roads, ports, and utilities, energy and renewable infrastructure have emerged as the primary drivers of demand, propelled by the green energy transition, policy incentives, and institutional investor appetite.

Because of their strategic importance and the significant societal benefits they provide, infrastructure projects traditionally have been funded primarily by governments. Private investors

²The NextGenerationEU (NGEU) fund was formally enacted on 14 December 2020, when the Council of the European Union adopted Regulation (EU) 2020/2094, establishing the European Union Recovery Instrument. This followed an agreement in principle by the European Council on 21 July 2020, where EU leaders endorsed the creation of the NGEU as a response to the economic challenges posed by the COVID-19 pandemic.

³The Inflation Reduction Act was signed into law by US President Joe Biden on 16 August 2022, with the goal of boosting clean energy and other key infrastructure investments. However, the subsequently elected US president, Donald J. Trump, pushed for a policy shift that no longer considers renewable energy as a priority. But the current administration has been prioritizing the construction of data centers, as well as their energy requirements. See the White House executive order “Accelerating Federal Permitting of Data Center Infrastructure” (23 July 2025), www.whitehouse.gov/presidential-actions/2025/07/accelerating-federal-permitting-of-data-center-infrastructure/. Also see the White House, “Winning the Race: America's AI Action Plan” (July 2025), www.whitehouse.gov/wp-content/uploads/2025/07/Americas-AI-Action-Plan.pdf.

historically faced limited opportunities in this asset class because these benefits could not be fully monetized. From the 1970s through the 1990s, austerity measures and rising sovereign debt led to a shift toward private capital, facilitated through privatizations and public-private partnerships. Banks initially led project financing, but following the Global Financial Crisis, stricter capital requirements under Basel III encouraged the growth of direct lending and infrastructure debt funds.

Institutional investors, including pension funds, insurance companies, and sovereign wealth funds, have increasingly sought long-duration, low-correlation assets. Infrastructure debt's combination of stable cash flows, tangible collateral, and low correlation with business cycles make it particularly attractive. The green energy transition further accelerated this trend during the 2010s. Green bonds, ESG mandates, and such initiatives as the Net-Zero Banking Alliance encouraged banks and pension funds to allocate capital toward renewable infrastructure, creating structural shifts in demand. Although some observers warn of a potential pendulum swing as inflationary pressures rise and capital costs increase, the long-term drivers supporting infrastructure debt remain robust.

Types of Infrastructure Debt

In general, the finance products used to finance infrastructure projects correlate with the development and operating life cycle of a project: At inception, uncertainty is high but expected return is also very high. As the project matures, the risk decreases and the cost of capital drops.

The debt instruments involved at each stage of an infrastructure project match the evolution of the project's life cycle. The process begins at the development finance stage, moving to construction finance, to operations finance, and finally holding-company-level finance. We discuss each stage in turn.

Development Finance

Early financing of an infrastructure project is important in order to build a stable foundation on which to develop further and seek future financing. This first phase of the project ranges from initial exploratory work to the ready-to-build (RTB) stage.

The development stage of an infrastructure project demands significant preparation work and is often beset with uncertainty. Therefore, providing the right financing is key to guaranteeing the project's viability. Typically, a range of instruments and parties are involved in financing at the initial stage.

Governments and organizations often support the funding of feasibility, environmental impact, and technical assessments for infrastructure projects through grants. These initial assessments are critical to determining the project's overall viability, areas of risk, and long-term viability. Although direct grants are provided, governments may also support the initial stages of this process by providing tax incentives, subsidies, or guarantees to offset the initial investment burden and draw private sector capital.

Seed capital is generally supplied in the form of initial equity investment from the project sponsor or private investors. Seed capital is used to finance upfront costs, such as purchasing land, permitting, and preliminary planning and designing works. Development finance institutions (DFIs),

such as the World Bank and regional development banks, are also critical at this stage. These organizations provide concessional lending and technical support, especially to developing markets, to help reduce the risk of the project and bring in other sources of capital.

Public-private partnership (PPP) models can also play a part during the project's inception. Under the PPP model, the public sector can provide initial capital funding or guarantees to enable it to attract private sector partners. This cooperative method ensures the risks are divided properly and allows for the smooth progression to the next stages of development and financing.

For community-level or small-scale infrastructure projects, crowdfunding now offers an innovative means of raising funds. Using the internet, project developers can solicit small donations from numerous people, financing initial work in a decentralized and often quicker way.

Last but not least, early-stage debt instruments are occasionally used to provide immediate liquidity needs. Short-term financing (until more long-term financing is secured) is provided by bridge loans, generally from commercial banks. Convertible debt is another frequently used instrument, whereby the early investors assume the higher risk for the chance to convert the debt to equity later, tying the investors' interest to the long-term success of the project.

These proceeds pay for all the pre-RTB stages of a project, including the pre-studies, the land permits, and numerous authorizations from the regulatory authorities. By obtaining this combination of financing at the initial stage, project developers are able to provide their infrastructure project with the resources required to proceed through the planning, design, and initial development phases.

This base funding is essential to attract the larger capital and finance required for the construction and operational phases. The earlier in the project, the lower—and the riskier—the required capital is because the project's "hit ratio" (the percentage of proposed deals or investment opportunities that an investor successfully closes) is still relatively low at the exploration stages. Drawdowns at this stage are generally low, short term, and high margin. At this stage, investors are exposed to high loss given default but also command pricing that is expected to cover those higher-probability and high-impact potential losses.

Generally, the farther along a project is toward the RTB stage, the greater the chance of a special purpose vehicle (SPV) being established to ring-fence the project's cash flows from the rest of the developer's business, as we explain in the next subsection. The debt component is usually financed through next-stage—and more affordable—construction financing.

Construction Finance

The construction finance stage begins when all the required permits have been secured and the project is found to be both financially and technically feasible.

During the construction stage of the project, there are high capital expenses and increased project execution risk—the latter mitigated by closely monitored cash flows: Drawdowns are subject to both lender approval and satisfactory project progress. Consequently, a strong and adaptable finance structure is essential to enable the project to run on schedule and according to budget. An array of funding mechanisms can be used at this stage.

Equity financing remains a central support during this phase. Project sponsors, which can be private companies, consortia, or the public sector, provide further equity capital to fill gaps and offer continued commitment. Private equity funds also invest in the construction stage, injecting capital against equity holdings in the project. Sponsors or equity investors with an overall portfolio of infrastructure projects, held in a holding company, may attempt to maximize returns through back leverage—that is, raising senior debt at the holding-company level, collateralized by their equity holdings in the project’s SPV (see the subsection on holding-company financing for more detail).

Most construction finance is secured through debt vehicles, mainly construction loans. Direct loans are provided mainly by commercial banks, either on a corporate basis or, more often, on a project finance basis. Under project finance, the loans are syndicated across various banks or institutions, facilitating risk dispersion among several lenders. These loans are generally structured as drawdown facilities, whereby the funds are released in tranches according to the schedule linked to construction milestones. No principal payments are made for the lending period; payments start only when the project is operational and is generating revenue.

In addition to senior debt, the gap between debt and equity can be bridged with the use of mezzanine financing. This hybrid capital generally exists in the form of subordinated debt or preferred equity, and it can even have conversion options upon default. Mezzanine instruments may be more expensive than senior debt, but they offer higher flexibility and can increase the capital structure without diluting the sponsors’ controls.

For high-quality, bankable projects, project finance—arranged through a specific SPV—is typically preferred. By ring-fencing all the project-related cash flows and liabilities at the SPV level, project finance structures give clear visibility of return on capital while insulating the sponsors’ balance sheets from project-specific risks.

Although theoretically project bonds may be issued in the construction stage, such a scenario is relatively rare because they are fully funded. The construction works generally need to have financing solutions with flexible release schedules to adjust to the uncertain timing of capital outlays. For this reason, bonds tend to be issued following construction, at the refinancing stage, when the project has been de-risked and has regular revenues.

PPPs are also widely used to finance construction. Under the terms of such partnerships, the private sector invests initial capital in return for long-term rights to revenue, such as user payments or availability payments. Governments also provide support to the construction stage through financing, guarantees, and milestone payments in order to lower the risk to private investors.

DFIs and export credit agencies (ECAs) have played a central role for construction finance across many emerging markets. DFIs, including the International Finance Corporation and regional development banks, offer loans and guarantees to offset political and credit risks, thus attracting further private funds. ECAs facilitate the export of goods and services through the provision of loans, insurance, or guarantees to the project developers to acquire equipment and inputs from their domestic economy.

Additionally, there is also financing from the supplier and contractor. The vendors and engineering, procurement, and construction (EPC) contractors can provide deferred payments,

effectively financing part of the buildout themselves. Moreover, completion bonds and performance guarantees provided by the contractor are key credit enhancements, supporting a timelier and on-budget project completion.

Through this combination of funding sources, the construction stage of the project can be adequately funded, risk is mitigated, and the project is kept on track. Proper finance planning and management at this stage are important to achieve the infrastructural project's eventual completion and operational success.

Operations Finance

Once an infrastructure project reaches commercial operation, the financing structure typically transitions from construction-oriented instruments to long-term, stable sources of capital. At this stage, project risk is significantly reduced: Technical completion has been achieved, key contracts (such as offtake or availability agreements)⁴ are active, and revenue generation has commenced. As a result, the project becomes more attractive to a broader range of lenders and investors seeking predictable cash flows and lower risk exposure.

Senior debt refinancing is one of the primary financing sources during the operations phase. The original construction loans, often shorter term and higher cost, are commonly replaced by long-term loans or project bonds with more favorable terms. These instruments allow for extended amortization schedules and reduced interest margins, reflecting the project's improved credit profile. Institutional investors, such as pension funds, insurance companies, and infrastructure debt funds, frequently participate at this stage, attracted by the long-duration and inflation-linked characteristics of infrastructure cash flows.

In such sectors as energy and transportation, revenues are often underpinned by long-term contracts, such as power purchase agreements (PPAs), concession agreements, or availability-based payment schemes, which further enhance the creditworthiness of the project. These arrangements help stabilize cash flow projections and support the use of such fixed-income instruments as green bonds, which are increasingly popular for renewable and sustainable infrastructure assets.

Junior debt, also referred to as subordinated or second-lien debt, can play an important role in the capital structure during operations. Although subordinated to senior debt in the event of default, junior debt typically offers higher yields and is often used to optimize the overall cost of capital or to support distributions to equity holders. It is commonly provided by infrastructure debt funds, mezzanine lenders, or even DFIs seeking to catalyze further private investment. In some cases, junior debt may be structured with payment-in-kind (PIK) features or flexible repayment schedules to accommodate cash flow variability, particularly in projects with seasonal revenue patterns or ramp-up periods.

⁴Offtake and availability agreements are long-term contracts whereby the infrastructure users, the users of its output, or the government, as the case may be, make regular and pre-agreed payments to the project in exchange for its output or availability. Examples of such contracts include power purchase agreements (in the case of an electricity plant), concession agreements (e.g., for a road or an airport), and availability-based payments (e.g., for a hospital or a road).

In mature operational projects, cash sweeps⁵ are often embedded in financing agreements to ensure that excess cash is used to accelerate debt repayment. This arrangement provides lenders with greater downside protection and can reduce overall financing costs over time.

Additionally, sponsors may re-leverage the project at this stage, extracting value through dividend recapitalizations or refinancing transactions. Re-leveraging is especially common when a project has consistently outperformed initial forecasts, allowing sponsors to optimize returns while maintaining acceptable debt service coverage ratios.

Operations-phase financing also benefits from the growing use of ESG-linked instruments. Lenders may offer pricing incentives for projects that meet predefined sustainability metrics, aligning investor interests with broader policy goals and enhancing the project's appeal in capital markets.

Holding-Company-Level Finance

The previous sections focused on project-specific or project portfolio-specific financings. At times, however, project sponsors try to enhance their risk-return equation by leveraging their portfolio of equity participations at the holding-company (HoldCo) level.

HoldCo financing refers to the use of debt raised at the level of the holding company that owns the equity stake in one or more infrastructure projects. Because it is not lent directly to the SPV that both operates the project and holds its assets and liabilities, HoldCo debt is considered riskier than project-level debt. The higher risk stems from the fact that HoldCo financing is more remote from the cash inflows of the operating (project) company and is serviced through upstream distributions—typically dividends—paid from the project company to the holding entity. This structure allows sponsors to either finance their equity commitments or monetize part of their investment in operational assets without diluting ownership.

Unlike traditional project finance, which is typically nonrecourse and secured against the cash flows and assets of the underlying project, HoldCo financing is structurally subordinated. Lenders at the HoldCo level do not have direct security over project assets and must rely on the residual cash flows that remain after the project has met all its senior debt obligations, operational expenses, and reserve requirements. As a result, HoldCo debt carries a higher risk profile and commands higher returns compared with senior project-level debt.

For equity investors, HoldCo financing offers greater flexibility in capital management, enabling them to recycle capital or enhance returns through financial leverage at the portfolio level. It introduces additional repayment obligations, however, which must be met from equity cash flows, thereby increasing the volatility of returns and reducing downside protection. For lenders, the absence of direct recourse and asset-level security translates into higher credit risk, especially in the event of underperformance or cash flow stress at the project level. To mitigate these risks, HoldCo loans often include tighter covenants, cash sweeps, dividend traps, and sometimes intercreditor agreements that limit distributions from the SPV if financial performance deteriorates.

⁵Cash sweeps are a feature of financings whereby the excess cash generated by the project, or a portion thereof, is allocated to the repayment of principal rather than to the equity holders.

In sum, HoldCo financing presents a trade-off: It enables more efficient capital structuring and return enhancement for equity sponsors but introduces a higher degree of financial risk for both investors and lenders, reflecting its subordinated position in the infrastructure capital stack.

Types of Infrastructure Investors

This section details several distinctive types of investors with recurring appetite for infrastructure debt. We begin by describing their main categories and their characteristics.

Commercial banks have traditionally been the cornerstone of infrastructure finance, particularly during the early stages of a project's life cycle. They typically provide senior debt, including construction loans, revolving credit facilities, bridge financing, and letters of credit. Banks are especially active in underwriting and syndicating deals, offering relatively short- to medium-term financing, usually with tenors ranging from 5 to 10 years. Although risk appetite varies by institution, banks are generally more willing than long-term institutional investors to take on construction and development risk. In recent years, however, regulatory pressures under such frameworks as Basel III have constrained banks' ability to hold long-term infrastructure loans on their balance sheets, prompting many to exit postconstruction phases through refinancing.

Infrastructure debt funds have become increasingly prominent, offering more flexible capital solutions and often targeting higher yields than traditional lenders. Typically established by asset managers or independent platforms, these funds focus on a range of instruments across the capital structure, including subordinated debt, mezzanine tranches, and HoldCo financing. Infrastructure debt funds tend to accept moderate to high risk profiles, including selective construction risk or exposure to emerging markets, in exchange for returns typically in the 6%-10% range. These funds' agility and structuring expertise allow them to support complex or transitional infrastructure projects, such as digital infrastructure buildouts, brownfield asset upgrades, and projects aligned with clean energy transition objectives.

Pension funds and insurance companies are among the most significant investors in infrastructure debt, driven by their need to match long-term liabilities with predictable, inflation-linked cash flows. These institutions typically target investment-grade senior debt and favor assets with stable, contracted revenues. Examples of such assets include toll roads with availability payments, regulated utilities, and renewable energy projects backed by long-term PPAs.

Infrastructure debt investors' preferred instruments include private placements, fixed-rate project bonds, and long-duration amortizing loans. Their risk appetite tends to be conservative, with a focus on operational assets or de-risked postconstruction projects. Regulatory frameworks such as Solvency II⁶ further incentivize these investors to seek qualifying infrastructure debt, which benefits from lower capital charges relative to corporate debt. Their buy-and-hold strategies make them ideal candidates for refinancing construction loans once the project is operational.

⁶Solvency II is an EU risk-based regulatory regime that governs how much capital insurance companies should hold in order to withstand shocks and protect policyholders.

Because of Solvency II obligations, some of these institutions require the projects to be wrapped by highly rated guarantors. These guarantees enable the insurers to use a much lower capital allocation to those positions, thereby improving the profitability of infrastructure debt investments compared with other, uncovered alternative asset classes.

DFIs and multilateral development banks (MDBs), such as the International Finance Corporation, the European Investment Bank, and the European Bank for Reconstruction and Development, also play a critical role in infrastructure debt markets, particularly in emerging and frontier economies. These institutions aim to achieve developmental impact and frequently provide concessional capital, credit enhancement, and risk mitigation instruments to mobilize private investment. Their lending is often long tenor and may be offered in local currency, with terms tailored to accommodate the complex risk environments of low-income countries. DFIs and MDBs are also instrumental in blended finance structures and may take first-loss positions in order to attract institutional capital. Although their return expectations may be aligned with market rates, their investment mandates prioritize social and environmental outcomes over purely financial performance.

Two key areas of involvement by government and supranational agencies are construction loans and emerging market infrastructure financing. Often in developing nations, no established or deep banking or institutional market exists for those projects, which calls for governments to bridge the gap between projects essential to a country's development and banks that are tied by prudential ratios and capital adequacy principles. A common structure is for ECAs or MDBs to guarantee certain tranches of infrastructure financings. At most banks, these guarantees benefit from a 0% risk weight, allowing the bank to compensate for the much higher risk weights of the uncovered tranches. In addition, government and MDB-covered loans are usually eligible for covered bond programs, whereby the bank can use the underlying project financing as collateral and borrow senior secured funding at cheaper rates. As a result, financing of these emerging market infrastructure projects becomes more affordable to the borrowers (usually—but not only—governments).

Sovereign wealth funds (SWFs) and other long-term institutional investors, such as large family offices or direct investment platforms, have also shown growing interest in infrastructure debt as part of broader real asset strategies. These investors often seek direct exposure to infrastructure projects or portfolios, sometimes co-investing alongside sponsors or acquiring entire tranches of debt in bespoke transactions. Their risk appetite can vary significantly depending on their mandate and internal capabilities, but SWFs are generally comfortable with holding illiquid, long-term positions and may be willing to assume moderate risk for enhanced returns. SWFs often play a strategic role in their home regions or in sectors of geopolitical interest, and they are particularly active in digital infrastructure, transport, and clean energy transition assets.

In addition to traditional lenders and institutional investors, credit risk insurers and significant risk transfer (SRT) investors play a complementary but critical role in the infrastructure debt market. Credit risk insurers—primarily private-sector firms and specialized monoline providers—offer guarantees and insurance products that mitigate specific credit risks, such as payment default, construction delays, and counterparty insolvency. These products are often used to enhance the credit profile of infrastructure debt, enabling senior tranches to meet investment-grade criteria and attracting a broader base of institutional investors. By shifting certain risks away from lenders, credit insurance also supports regulatory capital relief and helps improve loan pricing and distribution.

SRT investors, including structured credit funds, alternative asset managers, and hedge funds, provide risk capital in the form of first-loss or mezzanine exposure to portfolios of infrastructure loans. These transactions are typically executed through synthetic securitization or credit-linked notes, allowing originating banks to retain the loans on their balance sheets while transferring a meaningful portion of the underlying credit risk. For investors, SRT deals offer access to well-diversified infrastructure exposures with attractive risk-adjusted returns, often in the 8%–12% range, depending on the tranche and portfolio characteristics. For banks, SRT structures offer capital efficiency, portfolio optimization, and the ability to recycle balance sheet capacity into new lending, particularly in capital-intensive sectors, such as transport, energy, and digital infrastructure.

Together, credit risk insurers and SRT investors expand the risk management toolkit available in infrastructure finance. Their involvement enhances credit quality, increases funding capacity, and facilitates a more efficient allocation of capital—thereby supporting the scalability and sustainability of long-term infrastructure investment.

It is also worth noting that the dialogue between lender and borrower varies throughout the project life cycle. During the pre-project phase, it is quite common to see development-phase financings that demand a very close dialogue among the capital providers. Each drawdown will be tied to strict eligibility criteria in order to mitigate cost slippage and nonpayment risk. The cost of debt would be the highest during this phase. Debt providers at this stage are typically funds.

Once the project starts, the construction phase is also subject to a high level of scrutiny on the part of the lenders. The project sponsor typically sends regular updates of project progress and the level of achievement of key milestones (e.g., for a fiber rollout project, metrics might include a specific percentage of homes passed and a specific percentage of homes activated). During this phase, the cost of debt is lower than in the pre-project phase but still relatively high because of the higher credit risk, since the project is not yet generating cash flows. The complexity of loan monitoring and drawdown options makes this phase more adapted to bank financings, potentially with the help of guarantors.

When a project reaches operations, it is common for debt to be refinanced long term. At this stage, the refinancing can take the form of a project bond (potentially with a wrap), a bank loan, or a combination of both. The lenders are either banks, provided they have a low enough long-term cost of funds, or pension funds and life insurers seeking to match their long-term liabilities with matching long-term cash inflows.

In summary, the infrastructure debt market benefits from a diverse and complementary investor base. Banks remain central during the construction phase, while institutional investors and debt funds provide long-term capital and support refinancing. DFIs and MDBs enable investment in high-impact geographies and sectors, and SWFs offer flexible, strategic capital. This diversity enhances liquidity, promotes innovation in financial structuring, and ultimately facilitates the delivery of resilient, sustainable infrastructure around the world.

Infrastructure Debt Sub-Sector Asset Classes

Infrastructure investments have typically shown positive correlation with inflation, with real assets experiencing an increase in value in inflationary environments. This dynamic benefits

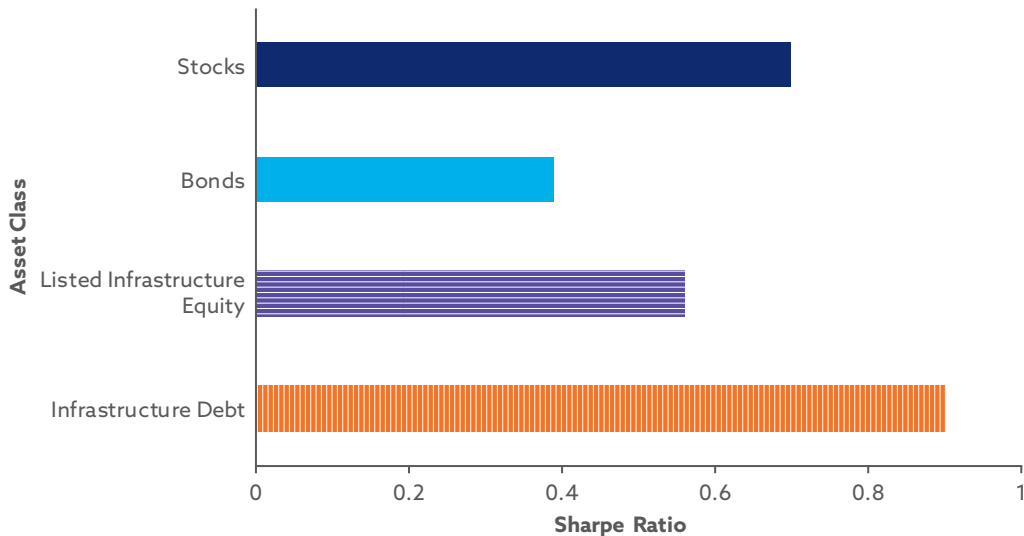
both equity and debt investors, by way of a higher valuation for equity owners or lower loss given defaults for creditors. Additionally, infrastructure investments also exhibit a relatively high overall return, a Sharpe ratio that is comparable or superior to listed equities,⁷ and, most importantly, low correlation of risk and return with listed investments.

Exhibit 1 shows how infrastructure investments have performed worldwide compared with other asset classes. It also illustrates how the asset class demonstrates higher risk-adjusted performance (measured by their Sharpe ratio) over time when compared with a number of alternative investment options.⁸

In addition, infrastructure as an asset class has benefited from exogenous factors of inflows. Investment opportunities have been numerous as infrastructure has become a central factor for countries seeking to improve economic competitiveness. In addition, the quest for cheaper and cleaner energy—driven by geopolitical and idiosyncratic trends—and the growing importance of digital infrastructure have played their part in the recent expansion of the infrastructure investment set, in both equity and debt.



Exhibit 1. Sharpe Ratio by Asset Class Worldwide, 2022



Sources: PortfolioLab for Sharpe ratio calculations on stocks, bonds, and listed infrastructure equity; for infrastructure debt, Global Infrastructure Hub, “Infrastructure Monitor 2022: Global Trends in Private Investment in Infrastructure” (2022), https://cdn.gihub.org/umbraco/media/5171/global-infrastructure-hub_2022-infrastructure-monitor-report-plus-esg-section_fa_2203.pdf.

⁷For example, expected return on core investments (e.g., roads or power grids) is around 7%–10%, in line with listed equities, with a volatility of returns that is less than half.

⁸For stocks, bonds, and listed infrastructure equity, respectively, we used the following indexes as proxies: the MSCI ACWI, Vanguard Total World Bond ETF, and the iShares Global Infrastructure ETF. The Sharpe ratios use a 10-year horizon, except for bonds, for which the index has only a 7.4-year horizon as of January 2026. Note that Sharpe ratios are known to be overstated for illiquid investments. Exhibit 1 is intended only to be suggestive.

Exhibit 2 shows the size of the debt allocated to infrastructure projects since 2010 by region. Although developed countries form the majority of overall spending, emerging markets are expected to keep fueling the growth of infrastructure debt in the coming years.

Infrastructure equity investments are typically made either by governments or by private investors—the amount of government intervention is typically dependent on the project’s strategic importance and the private investors’ appetite. To increase their return on equity and extract value from the potentially stable returns of infrastructure assets, private investors very often use debt to boost their returns through leverage. This has generated substantial growth across most sub-asset classes in the infrastructure debt investment universe. The most common of these sub-asset classes are described next.

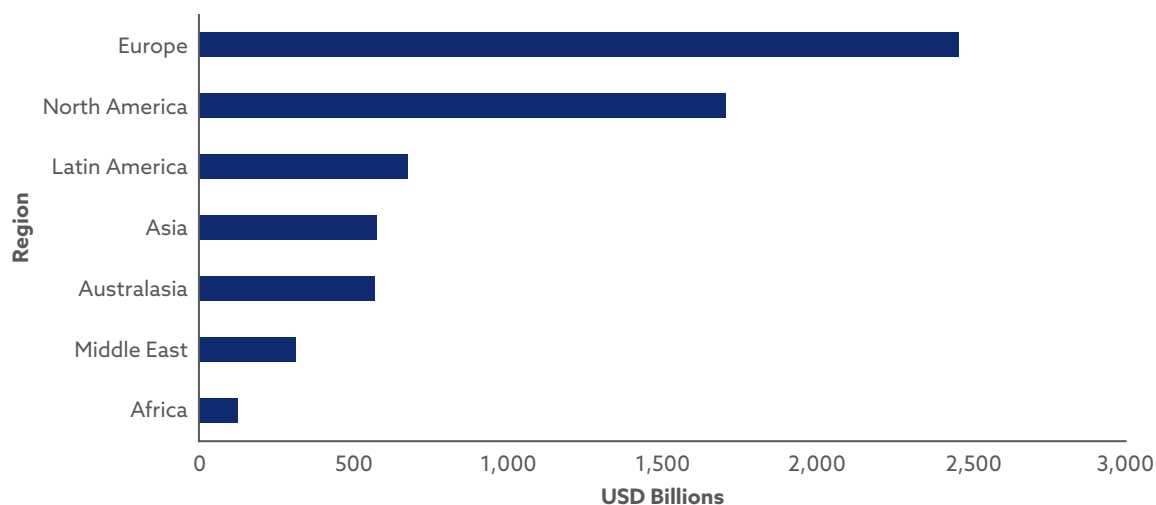
Energy Infrastructure

Energy infrastructure finance has gained market share in recent years as a share of project finance. The challenges posed by pollution, climate change, net-zero targets, and public demand for cleaner and more sustainable sources of energy have fueled rapid growth in renewable energy project financing, particularly in wind and solar energy generation (see **Exhibit 3**).

Renewable energy growth and its potential replacement of traditional sources of energy present different challenges in infrastructure implementation. For example, renewable energy sources often produce power intermittently (with the notable exception of hydraulic power): Solar panels do not generate at night, and wind turbines do not generate without wind. These differences explain the classification of energy infrastructure projects into several types: liquified natural gas, wind, solar, batteries, hydropower, hydrogen, and waste-to-energy.

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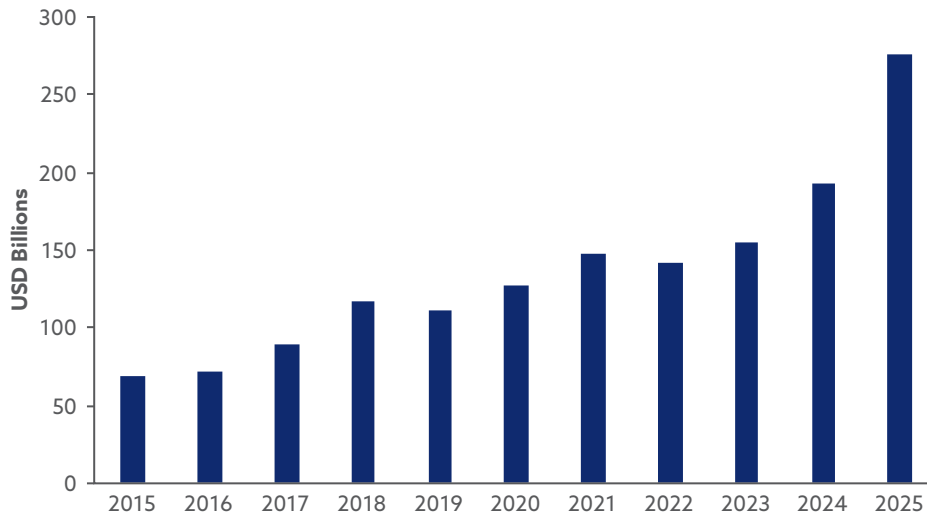
Exhibit 2. Infrastructure Debt Volume Distribution by Region, 2010–2025



Source: Infralogic.



Exhibit 3. Total Debt Raised for Renewable Energy Projects Worldwide, 2015–2025



Source: Infralogic.

Traditional Energy Infrastructure Projects

First, we will explore five traditional types of energy infrastructure.

Liquefied Natural Gas

With the world’s growing need for energy and overall willingness to reduce its reliance on oil and coal, liquefied natural gas (LNG) occupies a prime spot in the energy mix of most countries.

One of the primary motivations for developing LNG projects is to ensure a secure and dependable energy supply. These projects play a crucial role in diversifying natural gas sources, thereby reducing reliance on a single supplier or region. This diversification strengthens energy security for nations dependent on natural gas imports.

Environmental considerations also support the expansion of LNG projects. Natural gas, often delivered in LNG form, is widely regarded as a cleaner-burning fossil fuel. It emits fewer greenhouse gases and pollutants than coal and oil, aiding countries in their efforts to lower carbon emissions and achieve climate goals.

Furthermore, LNG facilitates the transition to a low-carbon economy by complementing renewable energy developments. It serves as a reliable backup power source, helping integrate variable renewable energy sources, such as wind and solar, into national power grids. LNG can be used to balance loads on the power grid, ensuring consistent energy supply and preventing blackouts.

Similar to other heavy industries, LNG projects contribute to employment creation during both the construction and operational stages, stimulating local economic growth. They also hold strong potential to ensure income streams for producing countries (which are often emerging markets), supporting both investments in infrastructure and funding for social initiatives.

LNG can be stored in large quantities, providing a buffer against supply disruptions and ensuring a continuous supply of energy during peak demand periods or emergencies. The development of LNG projects drives technological advancements in extraction, liquefaction, storage, and transportation, leading to greater efficiency and cost reductions in the energy sector.

In summary, LNG projects are essential for enhancing energy security, supporting environmental goals, promoting economic growth, and providing flexible and reliable energy solutions. They play a critical role in the global clean energy transition, helping ensure a sustainable and secure energy future.

However critical, those projects also carry significant risks at various levels. **Exhibit 4** summarizes the major risks linked to each phase of a typical LNG project.



Exhibit 4. LNG Project Risks

Project Phase	Risk Type	Description
Exploration and production	Geological	Unknown quality and quantity of reserves
	Technical	Drilling and extraction challenges
	Environmental	Project impact on the local ecosystem
	Regulatory	Permits and licensing
	Market	Volatility of gas prices
Liquefaction	Construction	Building delays and quality issues
	Technical	Complexities in the liquefaction process
	Safety	Handling and storing the gas
	Financial	Cost of capital, difficulties to secure financing
	Operational	Efficiency in operating the plant
Storage and loading	Storage	Requires very low temperatures
	Safety	Gas leaks or spills during storage and loading
	Technical	Quality and maintenance of equipment
	Regulatory	Compliance with safety and environmental regulations

(continued)

Exhibit 4. LNG Project Risks (*continued*)

Project Phase	Risk Type	Description
Shipping	Maritime	Sea transport risk (including weather)
	Safety	Spills and accidents during shipment
	Piracy	Risk of hijacking in certain regions
	Regulatory	Maritime regulations
	Environmental	Financial and environmental impact in case of spill or leak
Regasification and distribution	Technical	Difficulty of turning liquid gas back into gas
	Safety	Challenges linked to transport of gas
	Operational	Management of the regasification terminal
	Market	Volatility of gas prices
	Regulatory	Compliance with gas distribution regulations
Environmental and regulatory	Environmental	Potential impact at every phase
	Regulatory	Changes in regulations
	Community	Opposition from local communities
Economic and social	Economic	Economic context
	Social	Potential social opposition to the project
	Political	Political instability

The infrastructure required for liquefying and regasifying gas is typically substantial and demands significant financial investment. The associated risks vary depending on the phase of the project, however, necessitating different financing approaches at each stage. This variation enables project sponsors to optimize their weighted average cost of capital. Generally, as the project progresses through its life cycle, the cost of capital is expected to decrease. Using a combination of financing instruments—such as early-stage or corporate-backed funding, construction project finance, and long-term refinancing coupled with HoldCo financing—helps secure the most cost-effective funding.

Exhibit 5 offers a high-level summary of the financing methods commonly linked with each segment of an LNG project. Each phase may require a tailored mix of financing solutions to effectively manage the specific risks and requirements involved.

Wind

Wind-generated electricity plays a pivotal role in advancing the global green energy transition. A wind energy project involves deploying wind turbines to capture kinetic energy from the wind and convert it into electricity. The typical process includes identifying locations with high



Exhibit 5. LNG Project Financing Methods

LNG Project Component	Financing Type
Exploration and production	Equity finance, corporate loan
Gas treatment	Project finance (debt + equity)
Gas liquefaction	Project finance (debt + equity)
Gas storage	Project finance (debt + equity)
Loading facilities	Project finance (debt + equity)
Shipping	Project finance, leasing depending on case
Regasification terminal	Project finance, corporate debt (depending on sponsor)
Gas distribution network	Project finance, corporate debt (depending on sponsor)
Environmental mitigation	Grants, equity financing
Risk management	Insurance, hedging

wind potential, securing the required permits, and constructing the turbines. The electricity produced is then fed into the power grid, offering a clean and renewable energy supply.

Wind energy offers several advantages over conventional energy sources. It is a clean and inexhaustible form of energy because wind turbines operate by converting wind's mechanical force into electrical energy through a generator. Among energy sources, wind ranks among the lowest emitters of CO₂, along with solar, hydro, geothermal, and other renewables. Among traditional energy sources, only nuclear energy is comparable to wind in terms of emissions.

Beyond its environmental benefits, utility-scale (i.e., large-scale as opposed to home-scale projects) land-based wind energy is among the most cost-effective energy sources currently available.

With ongoing technological innovation, the cost efficiency of wind power continues to improve. Aside from significant initial capital investment, these projects have minimal ongoing operational expenses over the long run, with wind farms typically having an expected lifespan of 25–30 years.

In its onshore version, wind farms integrate well into agricultural and multipurpose rural areas, with project and equipment sizes adaptable to local needs. Wind projects also tend to generate consistent local economic benefits through tax revenues from public land occupation.

In summary, wind energy is emerging as a cornerstone of the global energy landscape. As a mature technology with vast scalability, wind energy offers a range of benefits: It complements more intermittent sources of energy, such as photovoltaic projects; brings down the marginal cost of electricity generation; and to a large extent replaces more traditional sources of energy generation, such as gas and nuclear power plants.

Wind projects come with their own set of risks, however, which vary by project phase and geographical context. **Exhibit 6** details these risks, categorized by phase and type. **Exhibit 7** offers a high-level summary of common financing methods for wind projects by phase.

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Exhibit 6. Wind Project Risks

Phase	Risk Type	Large Wind Project	Small Wind Project	Offshore Wind Project	Onshore Wind Project
Planning	Site selection	Environmental impact, land acquisition, community opposition	Limited site options, local zoning regulations	Marine environment impact, shipping lanes, fishing areas	Land use conflicts, wildlife impact
	Permitting	Complex regulatory approvals, lengthy processes	Local permits, less stringent but still necessary	Stringent marine regulation, potentially multiple jurisdictions	Local and national permits, environmental assessments
Construction	Cost overrun	High capital investment, unexpected expenses	Budget constraints, limited funding	High costs due to specialized equipment and logistics	Infrastructure costs, potential delays
	Delays	Supply chain issues, weather conditions	Limited resources, dependency on local contractors	Weather delays, logistical challenges, marine conditions	Weather conditions, land access issues
	Safety	Worker safety, heavy machinery, high-altitude work	Safety of small teams, limited safety equipment	Marine safety, underwater construction risks	Worker safety, terrain challenges
Operation	Maintenance	Regular maintenance, high costs, specialized technicians	Limited maintenance resources, higher relative costs	Difficult access, high maintenance costs, specialized vessels	Easier access, but still requires regular maintenance
	Performance	Efficiency issues, turbine reliability	Performance variability, less efficient technology	Harsh marine conditions affecting performance, corrosion	Variable wind conditions, potential for lower efficiency
	Market demand	Fluctuating energy prices, competition with other energy sources	Limited market access, dependency on local demand	Market volatility, dependency on grid connections	Market competition, integration with existing grid

(continued)



Exhibit 6. Wind Project Risks (*continued*)

Phase	Risk Type	Large Wind Project	Small Wind Project	Offshore Wind Project	Onshore Wind Project
Decommissioning	Environmental impact	Site restoration, waste disposal, recycling of materials	Limited resources for decommissioning, local environmental impact	Marine environment restoration, disposal of underwater structures	Land restoration, recycling of materials
	Financial	High decommissioning costs, securing funds for end of life	Budget constraints, securing funds for decommissioning	High costs due to specialized equipment and logistics	Costs associated with land restoration and material recycling



Exhibit 7. Wind Project Financing Methods

Phase	Large Wind Project	Small Wind Project	Offshore Wind Project	Onshore Wind Project
Planning	Equity financing, grants, government subsidies	Equity financing, local grants, community funding	Equity financing, government subsidies, strategic investments	Equity financing, grants, government subsidies
Construction	Debt financing, project financing, equity financing	Debt financing, local bank loans, community funding	Debt financing, project financing, equity financing, specialized marine financing	Debt financing, project financing, equity financing
Operation	Revenue from PPAs, operational cash flow	Revenue from PPAs, operational cash flow	Revenue from PPAs, operational cash flow, marine insurance	Revenue from PPAs, operational cash flow
Decommissioning	Reserve funds, decommissioning bonds, insurance	Reserve funds, local community funding, insurance	Reserve funds, decommissioning bonds, marine insurance	Reserve funds, decommissioning bonds, insurance

Solar

A solar energy project involves setting up solar panels that capture sunlight and convert it into electricity. This process generally includes selecting a site with high solar irradiance, securing necessary permits, and constructing the solar arrays. Once a solar project is operational, the electricity generated is fed into the power grid, offering a clean and sustainable energy solution similar to that of wind power.

The primary benefit of solar power is that solar panels produce electricity without emitting greenhouse gases or other pollutants. Replacing fossil fuels with solar power can substantially reduce carbon dioxide emissions, combating climate change.

The solar industry also supports job creation across various segments. Manufacturing, installation, maintenance, and research in the industry all require workers, thereby contributing to economic development.

Importantly, solar energy has become increasingly cost effective in most developed markets as government-led feed-in tariffs were greatly reduced. In the same markets, risk in private PPAs is also relatively lower, stemming from lower sovereign credit risk. Technological advancements and higher production volumes have dramatically reduced costs, positioning solar power among the most affordable energy sources available today. Solar projects also generate economic benefits for local communities through land lease and tax payments.

Solar power can be deployed in various settings, from household rooftops to utility-scale farms, and it can work in tandem with other renewables, such as wind, to provide a more stable and reliable power supply. Although utility-scale solar farms often occupy less land than wind farms, the amount of real estate needed can vary depending on the project.

Viewed from a broad perspective, the risks associated with solar projects are generally similar to those of wind projects, encompassing such stages as development, construction, and operation, as well as location-specific factors. **Exhibit 8** details these risks. With respect to financing, **Exhibit 9** explores the available approaches, which tend to be the same as for wind projects.

Increasingly, solar farms, which tend to be smaller than wind projects, are financed or refinanced on a portfolio basis, meaning that debt is collateralized by more than one project. Once the project is operating, the project sponsor will try to lower the cost of capital by refinancing the debt that was priced to include construction risk. In addition, electricity generation usually involves project-idiosyncratic risks. Therefore, financing these projects on a portfolio basis allows investors to diversify the risks and therefore to sustain higher levels of leverage at equivalent cost.

Furthermore, sponsors generate higher returns when electricity prices are low. Financiers usually prefer that electricity be sold via a PPA in order to lower the volatility of income. Financing projects as a portfolio allows the sponsor to leverage some projects without PPAs, relying on the stable cash flow of other projects and the diversification benefit of having several projects as collateral to the financing.

Batteries

In renewable energy, batteries store power from such sources as solar panels and wind turbines. This stored energy is used when production drops (e.g., at night or during low wind), keeping the power supply steady. Essentially, batteries make green energy more reliable and efficient.



Exhibit 8. Solar Project Risks

Phase	Risk Type	Description
Planning	Site selection	Environmental impact, land acquisition, community opposition
	Permitting	Complex regulatory approvals, lengthy processes
Construction	Cost overrun	High capital investment, unexpected expenses
	Delays	Supply chain issues, weather conditions
	Safety	Worker safety, heavy machinery, high-altitude work
Operation	Maintenance	Regular maintenance, high costs, specialized technicians
	Performance	Efficiency issues, equipment reliability
	Market demand	Fluctuating energy prices, competition with other energy sources
Decommissioning	Environmental impact	Site restoration, waste disposal, recycling of materials
	Financial	High decommissioning costs, securing funds for end of life



Exhibit 9. Solar Project Financing Methods

Phase	Financing Type
Planning	Equity financing, grants, government subsidies
Construction	Debt financing, project financing, equity financing
Operation	Revenue from PPAs, operational cash flow
Decommissioning	Reserve funds (cash reserves to provide for the project's future decommissioning), decommissioning bonds (bank guarantees to back the sponsor's commitment to decommission the project), insurance

In addition, batteries can play a very important role in helping achieve grid stability. Indeed, because the nature of renewable energy is generally intermittent and not perfectly correlated with energy usage, this dynamic places a heavy load on the grid at times. To better align the generation of renewable electricity with usage and help make prices less volatile, project sponsors increasingly add batteries to the projects.

Batteries store energy when it is produced and release it when needed. As a result, battery project sponsors usually make money because spot prices tend to rise with demand for electricity. Instead of selling the electricity upon generation, they wait until spot prices have increased to release electricity into the grid.

Batteries are of strategic importance to all stakeholders (investors, community, and government) for several reasons. First, they store electricity generated from intermittent renewable sources, such as solar and wind, ensuring a continuous power supply even when these sources are not actively generating energy. Also, by balancing supply and demand, batteries help stabilize the electrical grid and reduce the risk of blackouts. In addition, batteries power electric vehicles, which are crucial for reducing greenhouse gas emissions and decreasing reliance on fossil fuels.

Batteries also contribute to the decentralization of energy because they enable localized energy storage and distribution, promoting energy independence and resilience. Moreover, and in line with other renewable energy sources, batteries encourage innovation and economic growth: Advances in battery technology drive innovation in various sectors, including consumer electronics, medical devices, and industrial applications. Finally, batteries provide dependable backup power for homes, businesses, and essential services during power outages.

As a result, batteries are foundational to building a more sustainable, resilient, and efficient energy infrastructure. Their importance will continue to increase as innovation advances and more renewable energy sources are integrated into global power systems.

Exhibit 10 summarizes the phases of battery power projects and the risks associated with them, and **Exhibit 11** summarizes the various means of financing for each phase.



Exhibit 10. Battery Power Project Risks

Phase	Risk Type	Description
Project planning	Inaccurate feasibility studies, underestimation of costs, regulatory hurdles	Define project scope, objectives, and feasibility studies
Site selection	Environmental impact, land acquisition issues, local opposition	Choose an appropriate location for the battery storage system
Technology selection	Technological obsolescence, compatibility issues, supply chain disruptions	Decide on the type of battery technology (e.g., lithium-ion, lead-acid)
Design and engineering	Design flaws, engineering errors, cost overruns	Develop detailed system design, including layout and specifications
Procurement and installation	Delays in delivery, installation errors, equipment failure	Source and install battery systems and related infrastructure
System integration	Integration issues, grid instability, cybersecurity threats	Integrate the battery system with the existing power grid or renewable sources

(continued)

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Exhibit 10. Battery Power Project Risks (*continued*)

Phase	Risk Type	Description
Testing and commissioning	Testing failures, undetected defects, safety incidents	Test the system to ensure it meets performance standards
Operation and maintenance	Operational inefficiencies, maintenance errors, unexpected downtime	Manage and maintain the system to ensure optimal performance
Decommissioning and recycling	Environmental hazards, improper disposal, regulatory noncompliance	Plan for the end-of-life phase, including recycling and disposal of batteries

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Exhibit 11. Battery Project Financing Methods

Phase	Financing Type
Project planning	Grants, government subsidies, feasibility study loans, venture capital
Site selection	Land acquisition loans, environmental impact bonds, private equity
Technology selection	Technology-specific grants, research and development (R&D) funding, corporate investments
Design and engineering	Engineering design loans, project-specific loans, design-build finance
Procurement and installation	Equipment financing, construction loans, supplier credit lines
System integration	Integration project loans, grid connection grants, PPPs
Testing and commissioning	Performance bonds, testing and commissioning loans, operational readiness grants
Operation and maintenance	Operational loans, maintenance contracts, performance-based contracts
Decommissioning and recycling	Recycling grants, decommissioning bonds, end-of-life disposal funds

Hydropower

Hydroelectric power, often shortened to hydropower, generates electricity by harnessing the energy of flowing or falling water. This process typically involves building a dam on a river to form a reservoir or using the river's natural flow to generate electricity. Water released from the reservoir passes through turbines, converting kinetic energy into mechanical energy, which is then converted into electricity by generators.

Hydropower offers a range of strategic advantages that make it an important pillar in the energy landscape. It is a clean and renewable energy source that generates electricity without releasing greenhouse gases. Hydropower can also produce large volumes of electricity, making it suitable for both continuous (baseload) and on-demand (peak-load) energy needs.

One of its key strengths is flexibility. Hydropower plants can quickly adjust their output to match fluctuations in electricity demand, which is especially valuable as more intermittent sources, such as wind and solar, are integrated into the grid. Additionally, hydropower reservoirs provide important services beyond electricity generation, such as water supply, irrigation, and flood control.

Like many large infrastructure projects, hydropower developments also bring economic benefits. They create jobs, stimulate local economies, and can result in long-term savings on energy production.

Hydropower plays an essential part in the global transition to renewable energy. Its reliability and flexibility make it an ideal complement to variable renewable sources, such as solar and wind. It can deliver stable baseload power and be quickly ramped up or down to match peaks or ebbs in electricity demand, enhancing overall grid reliability.

By displacing fossil fuels, hydropower strengthens energy security and reduces exposure to the volatility of global energy markets. Despite its low emissions, hydropower can present notable environmental challenges, including habitat disruption and altered water quality, which must be managed carefully.

In summary, hydropower is a foundational element of the global energy strategy. It underpins sustainable development, bolsters energy security, and plays a crucial role in balancing more intermittent renewable energy sources as the world increasingly relies on them.

Exhibit 12 shows the steps and associated risks of each phase of a hydropower project, and **Exhibit 13** details the means of financing typically associated with each project phase. There are three phases in the “cycle of financing”: first, government and venture capital, when the project is still in exploratory phase; second, private equity and private debt, once the project becomes more certain but not yet “bankable”; and finally, bank debt, once the project can benefit from stable and reliable cash flow sources.

New Energy Infrastructure Technologies

In addition to the aforementioned traditional sources of energy production, some other upcoming technologies are on the horizon for wider implementation in the renewables space, such as hydrogen and waste to energy.

Hydrogen

An attractive and versatile element, hydrogen has potential uses as a fuel, an energy carrier, and an industrial feedstock. It is the universe’s most abundant element and may be derived from sources such as water, natural gas, and biomass. Hydrogen could potentially play a key role as an energy source, complementing the current utility-grade renewable power sources. It is also free from pollution: When used to power fuel cells or when burned inside conventional combustion engines, hydrogen leaves behind only water, making it an eco-friendly energy source.



Exhibit 12. Hydropower Project Risks

Phase	Risk Type	Description
Project planning	Inaccurate feasibility studies, environmental impact concerns, underestimation of costs, regulatory hurdles	Define project scope, objectives, feasibility studies, and environmental assessments
Site selection	Environmental disruption, land acquisition issues, local opposition, displacement of communities	Choose an appropriate location based on water flow, environmental impact, and logistics
Design and engineering	Design flaws, engineering errors, cost overruns, safety issues	Develop detailed designs for a dam, reservoir, and power station
Permitting and approvals	Regulatory delays, legal challenges, compliance issues	Obtain necessary permits and approvals from local, regional, and national authorities
Construction	Construction delays, cost overruns, safety incidents, environmental impact during construction	Build the dam, reservoir, power station, and related infrastructure
Commissioning and testing	Testing failures, undetected defects, operational inefficiencies	Test and commission the hydropower plant to ensure it meets performance standards
Operation and maintenance	Operational inefficiencies, maintenance errors, equipment failure, unexpected downtime	Operate and maintain the plant to ensure optimal performance and longevity
Decommissioning and restoration	Difficulty and cost of decommissioning due to the typically large size and environmental impact of such infrastructure	Plan for the end-of-life phase, including decommissioning the plant and restoring the site

Hydrogen has the added benefit of serving as an energy storage medium. It can store surplus electricity from renewables and convert this energy back to electricity when needed, balancing supply and demand.

Hydrogen can substitute for fossil fuels across many sectors, mitigating greenhouse gas emissions and supporting the development of the low-carbon economy. The contribution of hydrogen to the energy mix is growing for several reasons. It can be manufactured from surplus electricity provided by renewable power, converting and transporting renewable energy effectively, so it can blend well with the other forms of renewable energy. As another advantage in a renewables-dominant power mix, hydrogen has the potential to stabilize the power grid by accumulating surplus power during low-demand times and producing electricity at peak demand.

Exhibit 13. Hydropower Project Financing Methods

Phase	Financing Type
Project planning	Grants, government subsidies, feasibility study loans, venture capital
Site selection	Land acquisition loans, environmental impact bonds, private equity
Design and engineering	Engineering design loans, project-specific loans, design-build finance
Permitting and approvals	Government grants, PPPs, regulatory compliance bonds
Construction	Construction loans, syndicated loans, infrastructure bonds, MDB funding
Commissioning and testing	Performance bonds, testing and commissioning loans, operational readiness grants
Operation and maintenance	Operational loans, maintenance contracts, performance-based contracts
Decommissioning and restoration	Decommissioning bonds, recycling grants, end-of-life disposal funds, environmental restoration funds

In transportation, hydrogen fuel cells offer an efficient and clean alternative to conventional internal combustion engines for heavy-duty transportation and long-haul travel. Hydrogen can substitute for fossil energy in high-temperature industrial applications, lowering carbon emissions in those sectors that are hard to electrify. Thus, it is of particular interest to countries with heavy industry prominence. Most importantly, hydrogen is also producible domestically from several feedstocks, boosting energy security and lowering the need for imports.

In short, hydrogen will become an important element in a sustainable and resilient energy system. Its broad range of applications, clean energy capability, and versatility position it as an important ingredient for the future energy mix.

Exhibit 14 summarizes the key phases in hydrogen power projects and the risks involved, and **Exhibit 15** summarizes the various means of financing for each phase.

Waste to Energy

Waste to energy (WtE) is the conversion of municipal waste to useful forms of energy, including electricity, heat, and fuel, through such processes as incineration, gasification, and pyrolysis.⁹ In multiple ways, WtE is expected to play an important part in the future of energy. First, the amount of waste has exploded in recent decades, along with the overall growth of consumption both among the wealthy and among developing nations. Waste management is an especially current subject of attention among big cities, and WtE helps reduce the amount of waste going to the landfill, with all the implications to the surroundings.

⁹Pyrolysis is the heating, at 500°C or more, of an organic material in the absence of oxygen.

Exhibit 14. Hydrogen Power Project Risks

Phase	Risk Type	Description
Project planning	Inaccurate feasibility studies, underestimation of costs, regulatory hurdles	Define project scope, objectives, feasibility studies, and environmental assessments
Site selection	Land acquisition issues, local opposition, environmental impact	Choose an appropriate location based on resource availability, environmental impact, and logistics
Technology selection	Technological obsolescence, compatibility issues, supply chain disruptions	Decide on the type of hydrogen production technology (e.g., electrolysis, steam methane reforming)
Design and engineering	Design flaws, engineering errors, cost overruns, safety issues	Develop detailed system design, including plant layout and specifications
Permitting and approvals	Regulatory delays, legal challenges, compliance issues	Obtain necessary permits and approvals from local, regional, and national authorities
Construction	Construction delays, cost overruns, safety incidents, environmental impact during construction	Build the hydrogen production plant and related infrastructure
Commissioning and testing	Testing failures, undetected defects, operational inefficiencies	Test and commission the hydrogen plant to ensure it meets performance standards
Operation and maintenance	Operational inefficiencies, maintenance errors, equipment failure, unexpected downtime	Operate and maintain the plant to ensure optimal performance and longevity
Distribution and utilization	Distribution network issues, storage safety concerns, utilization inefficiencies	Develop infrastructure for hydrogen storage, transportation, and end-use applications
Decommissioning and recycling	Environmental hazards, improper decommissioning, regulatory noncompliance, high costs	Plan for the end-of-life phase, including decommissioning the plant and recycling components

Beyond waste disposal, WtE can also provide a sustainable energy solution, helping diversify sources of energy supply throughout the day. WtE has direct and indirect positive effects on greenhouse gas reduction. It prevents waste from ending up in landfills, thus reducing emissions of methane, an important greenhouse gas.

Exhibit 15. Hydrogen Power Project Financing Methods

Phase	Financing Type
Project planning	Grants, government subsidies, feasibility study loans, venture capital
Site selection	Land acquisition loans, environmental impact bonds, private equity
Technology selection	Technology-specific grants, R&D funding, corporate investments
Design and engineering	Engineering design loans, project-specific loans, design-build finance
Permitting and approvals	Government grants, PPPs, regulatory compliance bonds
Construction	Construction loans, syndicated loans, infrastructure bonds, MDB funding
Commissioning and testing	Performance bonds, testing and commissioning loans, operational readiness grants
Operation and maintenance	Operational loans, maintenance contracts, performance-based contracts
Distribution and utilization	Infrastructure financing, storage and transportation grants, utilization incentives
Decommissioning and recycling	Decommissioning bonds, recycling grants, end-of-life disposal funds, environmental restoration funds

WtE also displaces the use of fossil fuel energy to generate power. It has the potential to contribute positively to the recovery of valuable metals and substances from waste, increase recycling outputs, and lower raw material extraction requirements.

Specifically, WtE plants have the capability to deliver constant baseload power to the grid, helping maintain stable and assured power generation, unlike wind and solar which depend on the weather. Furthermore, WtE production can naturally occur close to areas that demand energy. WtE plants may be located close to urban areas to save energy transmission losses and produce local energy solutions.

WtE promotes the circular economy model by transforming waste into valuable material and energy, thus closing the loop of resource utilization. In addition, well-managed WtE plants reduce the environmental footprint of waste disposal.

Exhibit 16 presents the key phases of a WtE power project along with the risks involved, and **Exhibit 17** explores the types of financing typically used by WtE project sponsors.

Digital Infrastructure

Increasingly the object of long-term infrastructure investment and project finance, digital infrastructure has become a cornerstone of economic growth and social connectivity. The term *digital infrastructure* refers to the broad range of assets that includes fiber-optic broadband

Exhibit 16. WtE Power Project Risks

Phase	Risk Type	Description
Project planning	Inaccurate feasibility studies, underestimation of costs, regulatory hurdles, environmental impact	Define project scope, objectives, feasibility studies, and environmental assessments
Site selection	Land acquisition issues, local opposition, environmental concerns	Choose an appropriate location based on waste availability, environmental impact, and logistics
Technology selection	Technological obsolescence, compatibility issues, supply chain disruptions	Decide on the type of WtE technology (e.g., incineration, gasification, anaerobic digestion)
Design and engineering	Design flaws, engineering errors, cost overruns, safety issues	Develop detailed system design, including plant layout and specifications
Permitting and approvals	Regulatory delays, legal challenges, compliance issues	Obtain necessary permits and approvals from local, regional, and national authorities
Construction	Construction delays, cost overruns, safety incidents, environmental impact during construction	Build the WtE plant and related infrastructure
Commissioning and testing	Testing failures, undetected defects, operational inefficiencies	Test and commission the WtE plant to ensure it meets performance standards
Operation and maintenance	Operational inefficiencies, maintenance errors, equipment failure, unexpected downtime	Operate and maintain the plant to ensure optimal performance and longevity
Waste collection and handling	Collection and transportation issues, handling safety concerns, inconsistent waste supply	Develop infrastructure for waste collection, transportation, and preprocessing
Decommissioning and recycling	Environmental hazards, improper decommissioning, regulatory noncompliance, high costs	Plan for the end-of-life phase, including decommissioning the plant and recycling components

network infrastructures, mobile telecom towers, data centers, and undersea cable platforms. These installations underpin the digital economy, facilitating high-speed internet, cloud computing, streaming services, and mobile communication—services now regarded as public and private utilities.

The growth of digital infrastructure projects is fueled by the exponential consumption of data, the growing adoption of cloud services, the deployment of 5G technology, and the global



Exhibit 17. WtE Power Project Financing Methods

Phase	Financing Type
Project planning	Grants, government subsidies, feasibility study loans, venture capital
Site selection	Land acquisition loans, environmental impact bonds, private equity
Technology selection	Technology-specific grants, R&D funding, corporate investments
Design and engineering	Engineering design loans, project-specific loans, design-build finance, private credit
Permitting and approvals	Government grants, PPPs, regulatory compliance bonds, private credit
Construction	Construction loans, syndicated loans, infrastructure bonds, MDB funding
Commissioning and testing	Performance bonds, testing and commissioning loans, operational readiness grants
Operation and maintenance	Operational loans, maintenance contracts, performance-based contracts
Distribution and utilization	Infrastructure financing, storage and transportation grants, utilization incentives
Decommissioning and recycling	Decommissioning bonds, recycling grants, end-of-life disposal funds, environmental restoration funds

initiative to close the digital divide. Digital inclusion is also being championed by governments and regulators as a development agenda, particularly for underserved rural and remote communities. Thus, digital infrastructure is not only a commercially sustainable asset class but also a strategic asset class, supporting national competitiveness and social and economic inclusion.

From the perspective of project finance, digital infrastructure has both desirable attributes and unique challenges. These projects tend to have stable long-term free cash flows originating from usage-based charges, colocation agreements,¹⁰ or long-term leases to telecom or large technology companies. This revenue stability, along with the generally low operating expenditures and high asset scalability, makes digital infrastructure attractive for structures under project finance—especially SPVs with contracted revenues.

The financing strategy for digital infrastructure projects, however, depends on the asset class. Fiber networks—specifically, wholesale or open-access networks—have generally been financed with senior debt, sponsor equity, and sometimes grants or subsidies within areas of high demand. Such subsidies are closely anchored to long-term capacity agreements with telecom operators or the public sector to reduce the risk of demand. Telecom towers have instead been

¹⁰Data centers can be divided into two distinct types: collocated, meaning that the data center will be used by more than one tenant, and hyperscale, whereby the entire facility is occupied by a single tenant, often a US tech giant.

supported through triple net lease arrangements with mobile network operators, generating stable cash flows for 10–20 years.¹¹ These features have facilitated tower portfolios being viably financed and refinanced across project bonds or securitizations.

Data centers are an especially power- and capital-hungry part of digital infrastructure. Their financing structure generally consists of high levels of sponsor equity, senior secured debt, and possibly mezzanine tranches for growth phases. Long-term colocation leases to enterprise customers or cloud providers are the revenue drivers for these projects.

In line with other infrastructure projects, development and operational risks in digital infrastructure are quite high. Key risk areas are power supply, redundancy (risk of cannibalization by other digital infrastructure facilities), and energy efficiency. As a result, there is specific demand for ESG-compliant, energy-efficient digital infrastructure as a means to ensure long-run cost competitiveness.

Risks range from technology obsolescence to delays in regulatory approvals for rights of way to deploy fiber, construction delays, and latency or downtime challenges upon operating the facility. Most of the risks, however, can be addressed using strong contractual regimes, qualified project sponsors, and the right guarantees of functionality from technology and construction supply partners.

Exhibit 18 summarizes the key phases in a digital infrastructure project along with the associated risks. As with the project types discussed in previous sections, those phases are financed with specific financing tools, as shown in **Exhibit 19**.

In sum, digital infrastructure is a rapidly expanding and strategically critical part of the infrastructural space. Its scalability and contractually structured cash flows, as well as its congruence with the global digitalization movement, position it increasingly frequently in the sights of project finance. Although digital infrastructure is subject to particular operational and technology-related risks, it also provides investors and lenders with the chance to finance economically critical and socially beneficial assets.

Transport Infrastructure

Transportation infrastructure has been at the heart of economic development, trade facilitation, and regional integration for decades, and it remains highly attractive to long-term capital through project finance. The asset class covers a wide array of facilities serving public use, such as toll roads, bridges, tunnels, rail links, airports, and seaports. These assets tend to play a key role in increasing mobility, alleviating congestion, optimizing logistics efficiency, and linking rural areas with urban economic hubs—features critical to the growth strategies of both developed and developing economies.

The need for transportation infrastructure is driven by a growth spurt in urbanization, the increase in global trade volumes, and the aging of legacy infrastructures with capacities to upgrade or expand. Conversely, governments increasingly rely on private sector

¹¹A triple net lease is a commercial lease agreement in which the tenant pays the base rent plus three additional costs: property taxes, building insurance, and maintenance. This arrangement gives the tenant more control over the upkeep of the property while providing the landlord with a more predictable income stream.

Exhibit 18. Digital Infrastructure Project Risks

Phase	Risk Type	Description
Project planning	Inaccurate demand forecasts, underestimated costs, changing regulatory environment	Define business case, demand assessment, and market studies
Site acquisition	Land acquisition delays, zoning and permitting issues, local opposition	Secure rights of way, data center sites, or tower locations
Technology selection	Obsolescence, vendor lock-in, interoperability risks, high capex requirements	Choose the appropriate network, hardware, and software infrastructure (e.g., fiber versus wireless)
Design and engineering	Design flaws, cost overruns, security vulnerabilities	Develop system architecture, network layout, and capacity planning
Permitting and approvals	Regulatory delays, compliance failures, political intervention	Obtain necessary local, national, or environmental permits
Construction and installation	Installation delays, capex overruns, subcontractor risks	Build out fiber networks, towers, or data center infrastructure
Commissioning and testing	Performance shortfalls, equipment failure, integration issues	Test for connectivity, latency, throughput, and redundancy
Operations and maintenance	Network outages, cyberattacks, maintenance errors, staffing shortages	Run and maintain network or facility to meet service level agreements
Customer acquisition	Weak uptake, client defaults, contract renegotiation	Execute leasing or service contracts with internet service providers, mobile operators, cloud providers
Decommissioning/ upgrades	High upgrade costs, stranded asset risk, shifting technology standards	Plan for asset upgrades or life-cycle replacement

investment to bridge funding gaps. Consequently, transportation assets are being provided through PPP models or long-term concession agreements, which transfer the construction and operating responsibilities, along with revenue entitlements, to private investors. Under such circumstances, project finance emerges as the preferred financing option through which risks can be ring-fenced at the asset level and funds can be raised off balance sheet.

From the perspective of project finance, transportation infrastructure provides inflation-indexed, predictable revenues when supported by long-term user-pay structures, such as tolls, ticket prices, landing charges, or freight charges. Availability payments¹² or shadow

¹²Infrastructure projects are long-term economic assets. To secure long-term financing, such projects often benefit from long-term availability payments, with an “offtaker,” or user of the infrastructure or its products, committing to pay predetermined cash flows to the project on the condition that the infrastructure is available and/or producing.



Exhibit 19. Digital Infrastructure Project Financing Methods

Phase	Financing Type
Project planning	Feasibility study grants, early-stage equity, seed funding from infrastructure funds
Site acquisition	Land acquisition loans, real asset private equity, public development incentives
Technology selection	Vendor financing, equipment leasing, strategic equity from technology partners
Design and engineering	Project-specific design loans, equity bridge loans, engineering contracts tied to performance milestones
Permitting and approvals	PPP frameworks, regulatory risk insurance, government-backed development funds
Construction and installation	Construction loans, syndicated loans, infrastructure debt funds, digital infrastructure bonds
Commissioning and testing	Performance-based milestone payments, testing completion loans, short-term bridge loans
Operations and maintenance	Revenue-backed loans, long-term senior debt, maintenance contracts, availability-based payments
Customer acquisition	Contract monetization (e.g., leasing receivable securitization), anchor tenant financing
Decommissioning/upgrades	Retrofitting grants, asset-backed refinancing, upgrade reserve accounts, green transition bonds

tolls¹³ provide revenue certainty under other structures where demand risk is too high to assume, even for private investors. These structures stabilize cash flows and make the projects more attractive (and generally cheaper) to potential lenders, facilitating the use of SPVs and multilevel capital structures with senior debt, mezzanine tranches, and sponsor equity.

The structures differ between asset types and geographies. Toll highways and roads are typically financed through syndicated loans and long-term bonds redeemed through user charges or payments made by the government. Airports and seaports, which have retail, logistics, and real estate elements, tend to attract project finance and corporate-type funding because they have mixed income streams. The construction of rail infrastructure, particularly high-speed and metro lines, tends to be undertaken under PPP structures with large public sector input and multilateral lending, mainly in developing markets. For all types of transport projects, the critical

¹³A shadow toll is a contractual payment made by a government, paid per user of the infrastructure or the quantity produced by the infrastructure.

financial measures, such as the debt service coverage ratio (DSCR),¹⁴ traffic projections, and life-cycle cost projections, drive the structuring and underwriting of the financing.

Although they have great promise, transport projects are fraught with significant risk, running from construction delay and cost overrun to traffic volume uncertainty and political/regulatory interference. Demand risk is especially acute for greenfield transport projects, where observed user take-up can differ significantly from projections owing to rival infrastructures, fuel price fluctuation, and/or macroeconomic factors. To insulate against such risks, sponsors may engage public authorities to provide guarantees, revenue floors, or minimum traffic guarantees. Strong engineering studies, construction contracts tied to performance, and long-term operations and maintenance (O&M) agreements are also key to securing returns and ensuring service levels in the face of decades of wear and tear.

Exhibit 20 highlights the risks related to each phase of a transport infrastructure project.

ESG factors have also influenced the financing of transportation infrastructure in recent years. Increasingly, investors are requiring new transportation assets to reduce emissions, improve integration among modes of transportation, and support sustainable urbanization. These factors have driven an increase in green bonds and sustainability-linked loans to fund electric rail corridors, low-carbon bus stations, and intelligent mobility platforms. Together, these dynamics make transportation infrastructure not only a conventional driver of economic growth but also a central factor to support the low-carbon energy transition.

Exhibit 21 summarizes the most common financing methods used in transport infrastructure projects.



Exhibit 20. Transportation Infrastructure Project Risks

Phase	Risk Type	Description
Project planning	Inaccurate demand or traffic forecasts, cost underestimation, political resistance, weak governance	Define objectives, feasibility studies, cost-benefit analysis, stakeholder engagement
Site selection	Land acquisition disputes, environmental concerns, local opposition, right-of-way delays	Identify and secure optimal corridor or location
Engineering and design	Design errors, geotechnical challenges, underestimation of scope or future capacity needs	Develop technical specifications, route layout, environmental and social impact assessments
Permitting and approvals	Regulatory delays, compliance risks, public scrutiny, legal appeals	Obtain regulatory, environmental, and construction permits

(continued)

¹⁴DSCR is the ratio between cash flow available for debt service and debt service payments (principal plus interest) in the relevant period.

Exhibit 20. Transportation Infrastructure Project Risks (*continued*)

Phase	Risk Type	Description
Procurement and contracting	Contractor default, poor contract structuring, procurement fraud	Select EPC contractors and define construction timelines and payment mechanisms
Construction	Construction delays, cost overruns, supply chain issues, labor disputes, safety incidents	Build physical infrastructure (roads, tracks, terminals, etc.)
Testing and commissioning	Technical failures, underperformance, delayed certification	Test systems, equipment, and network integrity prior to operations
Operations and maintenance	Traffic underperformance, high O&M costs, asset deterioration, inadequate maintenance funding	Operate asset in accordance with service-level standards; maintain safety and performance
Revenue collection	Demand risk, fare evasion, payment system failures, contract disputes	Collect user fees or receive availability payments (e.g., tolls, fares, leases, government payments)
Life-cycle upgrades/closure	Funding gaps, obsolescence, environmental risks, transition-related disruption	Conduct long-term rehabilitation, modernization, or eventual decommissioning

Exhibit 21. Transportation Infrastructure Financing Methods

Phase	Financing Type
Project planning	Feasibility study grants, government subsidies, sponsor equity, DFI feasibility loans
Site selection and land acquisition	Land acquisition loans, public sector funding, PPP pre-development funding, infrastructure private equity
Engineering and design	Engineering design loans, sponsor equity contributions, design-build financing, advisory funding from MDBs
Permitting and approvals	Government grants, PPP frameworks, regulatory risk insurance, development bank support
Procurement and contracting	Equity bridge financing, contractor guarantees, performance bonds, early-stage project finance facilities
Construction	Construction loans, syndicated project finance loans, ECA financing, infrastructure bonds (rare during construction), mezzanine debt

(*continued*)



Exhibit 21. Transportation Infrastructure Financing Methods (continued)

Phase	Financing Type
Testing and commissioning	Performance bonds, completion guarantees, bridge loans, operational readiness facilities
Operations and maintenance	Long-term senior project finance debt, project bonds, institutional private placements, infrastructure debt fund loans
Revenue collection	Revenue-backed refinancing, securitization of toll or fare receivables, concession-backed loans, availability-payment-backed financing
Life-cycle upgrades/modernization	Asset-backed refinancing, green bonds or sustainability-linked loans for low-carbon transport, maintenance reserve facilities, public coinvestment programs

Infrastructure Debt in Energy Transition: A European Case Study

Infrastructure debt has matured from a boutique financing technique into a major institutional asset class that underwrites the capital-intensive backbone of modern economies. The combination of fiscal stimulus and direct subsidies, the green energy transition, and the demand surge for electricity-thirsty digital infrastructure has elevated private infrastructure capital to record levels.

Yet the underwriting challenge has shifted. Banks have traditionally financed the predictability of long-term cash flows within power markets, but both the physical and commercial dynamics in those markets are changing with unprecedented speed. Historically, long-term contracted offtakes allowed banks to underwrite relatively stable cash flows, without the need for detailed scrutiny of production load profiles or the systemic effects of high penetration of renewable energy sources (wind and solar). That approach is no longer a viable basis for financing. Because intermittent renewables now increasingly dominate marginal power supply and hence set the price, cash flow stability depends far more on how projects perform in terms of hours of surplus energy, how exposure to cannibalization by other renewable energy sources is allocated, and whether volume risk is credibly mitigated.

This is why baseload-style offtake structures, once common in renewable project financing, are increasingly unbankable. Instead, emphasis is shifting toward offtake contract design, project portfolio strategies, and tail and refinancing risk allocation. All these approaches explicitly share and redistribute the aforementioned new risks across counterparties, preserving debt serviceability even under adverse market conditions.

Europe—the Nordic region in particular—offers a practical laboratory for how contract design, power grid dynamics, and lender behavior interact to determine infrastructure project bankability. This section aims to bring those lessons into a broader context, so that other regions can

avoid the “early bird” mistakes observed in the Nordic region. This case study further explains how financing structures, sequencing, and policy choices can convert renewable volatility into investible, long-tenor instruments.

Why the Underwriting Question Has Changed

The popular story about renewable energy projects is familiar: Falling technology costs have lowered the levelized cost of electricity (LCOE)¹⁵ and created project pipelines several orders of magnitude higher than they were at the industry’s inception. As cost-competitiveness has increased, lenders have deployed vast capital into this asset class. For many years, during which renewable penetration remained fairly shallow, large allocations posed little problem, and project returns looked resilient.

Although this narrative is technically true, it obscures a critical underlying point. Lenders do not underwrite average prices or falling production costs. Rather, they underwrite realized cash flows, the timing of those receipts, and the risk profile of offtakes.¹⁶

Renewable generation assets concentrate production into weather-dependent and daylight-driven hours, creating capture price profiles that diverge materially from both system and node averages.¹⁷ When transmission lines are congested, large bursts of renewable generation (from wind and/or solar) can push wholesale electricity prices downward (sometimes even below zero) for extended periods. Under such conditions, a renewable project that appears profitable in a simple financial model may struggle once more realistic factors are included. These factors include the following:

- Cannibalization, in which nondispatchable renewables drive down each other’s prices—because during the times when one project is generating the most power, others also generate, and vice versa for periods of low generation
- Curtailment, which occurs when a system operator is forced to shut down or reduce output because the grid is either full or not in balance
- Basis risk, when prices differ between the project’s price area and the system price

When such effects are factored into normal production forecasts, a renewable energy infrastructure project’s financial ratios can fail to meet loan covenant requirements.

¹⁵LCOE is a standardized financial metric used to assess average cost of producing electricity from a specific generation asset over its useful life. It enables an apples-to-apples comparison across energy technologies (e.g., wind versus gas or solar versus nuclear).

¹⁶This risk profile concerns who bears the direct and indirect financial risks affiliated with the unique load profile of intermittent renewables. Such risks include volume risk, curtailment risk, and balancing costs.

¹⁷Some power systems, such as those in parts of the Nordics, are split into price areas (called node pricing) to better reflect transmission bottlenecks and supply/demand fundamentals in each region. Conversely, the system price reflects the “theoretical average price” absent consideration of regional constraints or market fundamentals.

Empirical Signals from the Nordics

European electricity markets have already experienced rapid increases in negative price episodes.¹⁸ Finland, for example, recorded roughly 700 hours of negative day-ahead pricing in 2024, a nontrivial share of the year that materially affects merchant outcomes.¹⁹ These episodes are not anomalies; rather, they are the path-dependent result of interacting supply-side growth and transmission grid bottlenecks.

Where negative price hours cluster, offtake contracts and hedging mechanisms are stress-tested in entirely different ways than would occur in a higher-margin, less correlated market. Lenders and trading counterparties in the Nordic countries have responded by innovating settlement mechanics, creating price floors, designing caps that are sensitive to load profiles and hours, and insisting on replacement arrangements for environmental attributes, such as Guarantees of Origin (GoOs).²⁰ Beyond financial engineering, such contractual innovations form the backbone of what makes an operating intermittent renewable plant viable as collateral to a long-term investor or financier in today's markets.

How Contracts and Structures Change Bankability

PPA contracts determine whether cash flows are predictable enough for long-tenor debt. A market price floor that eliminates downside settlement below a pre-agreed level can turn an otherwise volatile, spot market-exposed revenue stream into one that lenders view as reliable. This stability, however, depends on the credit quality of the counterparty or on a public guarantee mechanism, such as a contract for difference.

The overall trend for sellers to deal with negative price risk is to simply suspend settlement during negative price hours without a compensating revenue mechanism. Increased scrutiny when drafting PPAs, however, ensures that sellers do not face penalties or costs for negative price hours or balancing costs. Such penalties—which are typically negotiated between the parties within the context of risk allocation—could dilute an arrangement otherwise intended to provide stable and predictable cash flows for debt service, essentially making the project nonbankable.²¹

Structured caps in renewable energy infrastructure projects, introduced to limit extreme upside or to allocate negative-volume risk across counterparties, have also evolved in response to lender preferences. Taken together, these devices show that the difference between a financeable and an unfinanceable project can be a single paragraph in a PPA.

¹⁸Rapid renewables buildout, paired with inflexible industrial demand and limited export capacity, has resulted in periods of oversupply in the Nordic power markets. Given the intermittent production profile from renewable energy sources, such oversupply tends to occur during certain hours, resulting in negative prices.

¹⁹International Energy Agency, "Wholesale Electricity Prices Fell Further in 2024 As Energy Commodity Costs Declined," in *Electricity 2025* (2025), www.iea.org/reports/electricity-2025/prices/.

²⁰GoOs are "proof of renewable" certificates that allow electricity consumers to claim and verify that their energy comes from green sources, even though the physical electrons on the grid are naturally mixed.

²¹An example of increasing sophistication are the "pay-as-nominated" PPAs, whereby the buyer pays the generator for the amount of energy it promised to deliver (based on a production schedule from the generator), not the amount it actually produced. This approach shifts balancing costs and risks from the buyer to the seller. Although this approach increases the seller's risk, it also enables it to command a higher PPA price to compensate for this risk allocation.

Portfolio Aggregation, Blended Finance, and the Lender's View

Single-asset underwriting is the traditional infrastructure project finance model. Where cannibalization risk and wholesale spot power price volatility are significant, however, portfolio aggregation becomes the banker's tool of choice. By pooling assets across different technologies, project sizes, contracting profiles, and geographies or power markets, an investor can reduce revenue correlation and smooth cash flow distributions, thereby increasing DSCR headroom for the same nominal leverage.

Blended finance further complements this effect. Examples include cover from ECAs or first-loss tranches, which can convert marginal projects into investment-grade tranches that attract pension and insurance capital. These mechanisms work together. In markets where offtaker credit is shallow and intraday volatility is high, consolidation of revenue streams, export credit cover, or development finance (i.e., MDB) cover are often prerequisites for long-dated institutional debt for renewable assets.

Operational Realities That Underwriters Must Model

Forecasting frameworks must also evolve. Uniform, system-wide power price assumptions are no longer adequate for asset valuation. Instead, modeling needs to reflect the regional market (node) conditions where projects physically operate, including the real prices that infrastructure assets are likely to realize for their sold electricity (capture price), the risk of forced output reductions resulting from transmission constraints (curtailment), and revenues derived from providing grid balancing and stability services. Downside modeling cases should also account for sustained periods of depressed or negative power prices occurring in clusters, rather than treating such events as isolated tail risks.

Liquidity frameworks, including debt service reserve accounts sized for prolonged low-price periods and clear replacement arrangements for curtailed output, must increasingly be considered as part of a baseline covenant package for renewable energy infrastructure investment. Furthermore, any deal that relies materially on storage optimization (e.g., provided by a colocated battery energy storage system)²² should provide a detailed forecast of the various revenue streams that a battery storage asset can deliver and how it is being operated. The structuring should include balancing and frequency services to safeguard grid stability, as well as arbitrage trade opportunities resulting from the intraday power price cyclicity. Revenue projections need to be substantiated, considering the fact that income from balancing contracts, frequency control auctions, and intraday power price arbitrage is typically viewed as merchant revenues subject to price volatility. That is, unless a producer can demonstrate contract rollover probability and long-term stability of ancillary service markets.

²²Colocation refers to the deployment and operation of multiple energy assets (typically solar or wind, together with a battery energy storage system asset), behind a single grid connection point, to optimize cost, performance, and market participation.

A Pragmatic Underwriting Playbook

Practically speaking, lenders and sponsors should aim for a coordinated combination of the following:

- nodal-aware modeling that replaces system-price assumptions,
- covenant packages that reflect prolonged negative price stress,
- contractual settlement mechanics that balance buyer and seller incentives while preserving bankability, and
- portfolio-level diversification strategies that smooth capture correlation.

Sponsors should be prepared to accept hybrid credit enhancements at early stages and to design projects so that storage, flexibility services, and ancillary markets are embedded in the capital structure rather than being optional add-ons.

More importantly, however, policymakers play a catalytic role by prioritizing network upgrades, standardizing energy market designs, and providing temporary risk-sharing instruments that crowd in private capital without creating permanent fiscal liabilities. More specifically, policymakers need to ensure that buildout of renewables is calibrated with demand-side growth (and the load profile of such growth), which is key to minimizing negative/low price hours and hence addressing the underlying uncertainties discussed earlier.

One key feature in achieving the goal of building a viable renewables markets is to acknowledge and price the infrastructure value of balancing, capacity, and frequency control ancillary services (FCAS).²³ Historically, this value calculation has been provided for free by large-scale and by dispatchable power generators that can be turned on when needed, and whose large spinning turbines naturally help stabilize the frequency of the electricity grid. Providing predictable market features and price setting of such services will greatly enhance the bankability of renewable energy projects, giving cash flow visibility to assets that are critical to improving the physical and commercial stability of power grids and markets.

Conclusion

Although infrastructure debt has matured into a central pillar of global capital markets, its role is defined as much by evolving risks as by enduring fundamentals. The asset class still rests on tangible, long-duration assets with historically stable cash flows and low default rates. Yet its diversification across subsectors and financing structures underscores the complexity that investors must now underwrite.

Green energy transition assets, ranging from LNG to wind, solar, batteries, hydropower, hydrogen, and WtE, demonstrate how project life cycles require distinct financing solutions at each stage, from development equity and concessional lending to construction loans, mezzanine tranches, and long-term refinancing via project bonds. Digital and

²³FCAS markets produce and price the capability to rapidly increase/decrease power output (or demand) to keep power grid frequency within operational limits (typically 50 Hz or 60 Hz) in real time. These markets sit alongside energy markets but compensate providers for stability services as opposed to only for MWh production.

transport infrastructure adds further layers of technological, regulatory, and demand-side risk while also offering inflation-linked, contracted cash flows that remain attractive to long-term capital.

The financing stack is increasingly multilayered. Commercial banks dominate early-stage and construction risk. Institutional investors, such as insurers and pension funds, provide long-tenor, investment-grade capital. Infrastructure debt funds and HoldCo lenders offer higher-yield, subordinated exposures. And DFIs, ECAs, and credit insurers enable investor participation in higher-risk geographies. This diversity of capital sources has created both resilience and innovation, but it also requires careful calibration of risk allocation across tranches and sponsors.

Zeroing in on the renewables space, we have observed a shift in underwriting challenges. Intermittent renewable energy projects, such as wind and solar, along with the growing incidence of negative pricing episodes in liberalized power markets, mean that cash flow predictability now depends less on average system prices and more on the integrity of PPA structures, nodal-price modeling, portfolio aggregation, and ancillary service monetization. Lender emphasis is increasingly on contract mechanics, credit enhancements, and reserve structures, in addition to cannibalization risk in an effort to preserve debt serviceability.

In short, infrastructure debt remains defined by its defensive qualities, but its bankability is no longer assumed. Predictability of cash flows, once embedded in regulated utilities and long-term concessions, is now created through contractual innovation, blended risk-sharing, and portfolio strategies. The continued expansion of this asset class will depend on how effectively investors and policymakers can adapt these infrastructure debt structures to an environment where capital intensity is rising, technology is shifting, and volatility is structural rather than cyclical.

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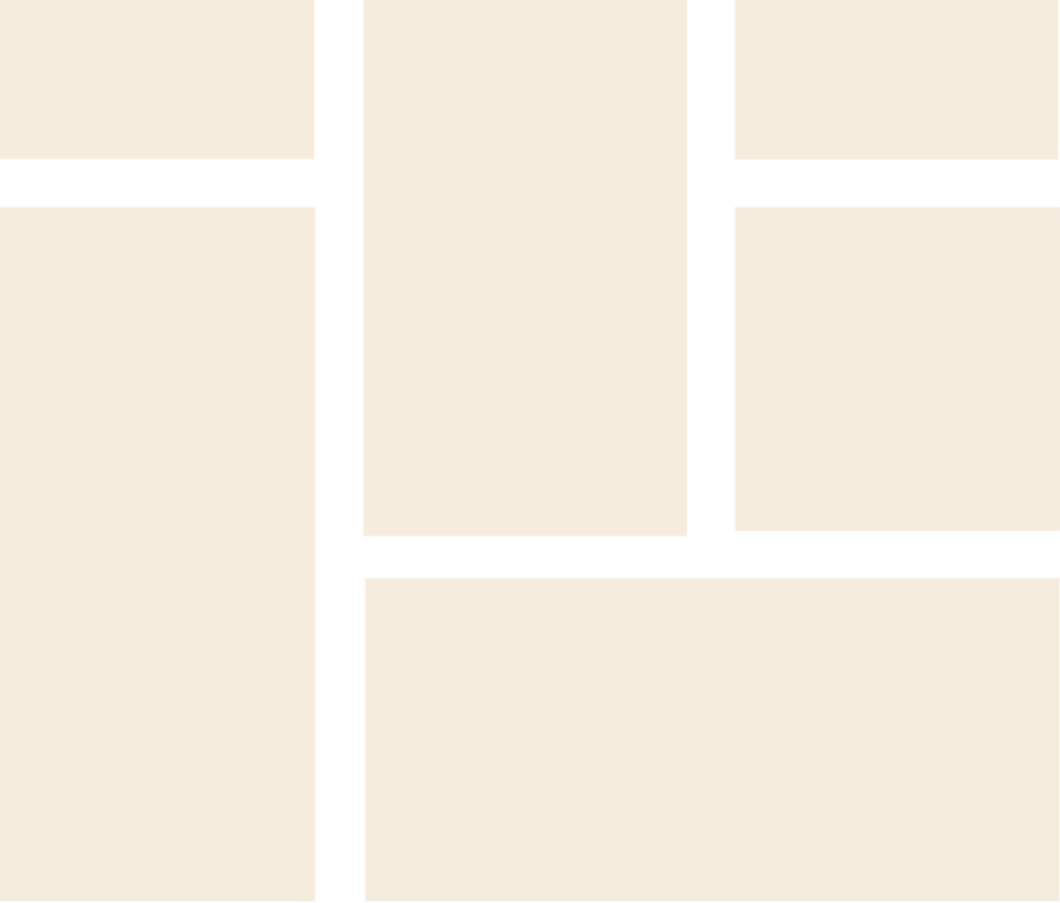
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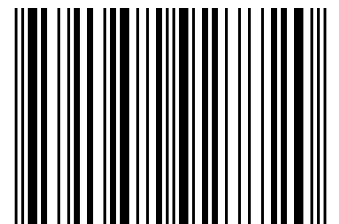
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ISBN 978-1-952927-72-0



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