WPKS

# Bridge technologies

## from a sustainable finance perspective

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# Zusammenfassung

Brückentechnologien spielen in der aktuellen Energie- und Klimakrise eine wichtige Rolle. Das prominenteste Beispiel in der aktuellen Diskussion ist die Nutzung von Flüssiggas (Liquid Natural Gas – LNG) und die hierfür erforderlichen Terminals an der deutschen Küste. Per Definition ist bei Brückentechnologien von vornherein klar, dass diese nur für eine Übergangszeit genutzt werden sollen. Dies wirft eine Reihe von grundsätzlichen Fragen zu den Brückentechnologien auf, von der gesellschaftlichen Akzeptanz über die Ausgestaltung von Regulierungen bis hin zur Bedeutung der Brückentechnologien für eine robuste Transformation zu einer klimaneutralen Wirtschaft. Im Hinblick auf den letzten Punkt ist es auch wichtig zu verstehen, wie – neben dem Staat als möglichem Finanzierer– nachhaltigkeits-orientierte Investoren grundsätzlich Brückentechnologien und die hiermit in Zusammenhang stehenden Infrastrukturprojekte als „nachhaltige“ Investitionsmöglichkeit sehen und wie sie die damit verbundenen Risiken einschätzen. Die vorliegende Untersuchung identifiziert wichtige Fragen von nachhaltigen Investoren bei Brückentechnologien, insbesondere mit Blick auf die Gesetzgebung im LNG-Kontext und zur anschließend vorgesehenen Nutzung für Wasserstoff. Dazu wurden deutsche Asset Manager befragt, die im Bereich nachhaltiger Anlagen und Infrastrukturinvestitionen tätig sind. Darüber hinaus wurden drei Unternehmen interviewt, die im Bereich LNG-Infrastruktur aktiv sind. Ziel war es zu verstehen, ob Investoren Brückentechnologien grundsätzlich als attraktiv und sinnvoll erachten und welche Rahmenbedingungen bei ihren Investitionsentscheidungen eine Rolle spielen. Es wurden insgesamt 14 halbstrukturierte Interviews durchgeführt. Als Ergebnis der Analyse wurden drei primäre Risikothemen im Zusammenhang mit Investitionen in Brückentechnologien

identifiziert. Zunächst wurden Risiken benannt, die allgemein mit der Nutzung der Brückentechnologie oder mit dem spezifischen Brückentechnologievorhaben verbunden sind. Dies sind  insbesondere regulatorische Risiken und Risiken, die sich am dem "Ende" der Nutzungsphase der Brücke ergeben. Zweitens wurden Risiken im Zusammenhang mit der Klassifizierung des Anlageprodukts identifiziert, insbesondere in Bezug auf die Schwierigkeit einer angemessenen Klassifizierung von Investitionen in Brückentechnologien innerhalb der bestehenden Klassifizierungssysteme für nachhaltige Anlageprodukte. Drittens wiesen die Asset Manager auf Risiken hin, die nicht mit einem bestimmten Projekt, sondern mit der Brückentechnologie im Allgemeinen einhergehen, darunter vor allem Reputationsrisiken für die eigene Organisation. Diese Risiken sind wichtige Gründe, die mögliche Investitionen aus dem Privatsektor in die Brückentechnologien und LNG-Vorhaben in Deutschland hemmten. Einige Interview-Partner wiesen darauf hin, dass andernorts, insbesondere in den USA, diese Risiken weniger relevant sind. In Deutschland ließen sich die wahrgenommenen Risiken durch transparente und verlässliche Transformations-Pfade – im LNG-Fall z.B. mit Blick auf den Markt für Wasserstoff – durch präzisere Kriterien für die Klassifizierung von Transformations-Investment-Produkten und durch eine wissenschaftlich fundierte und proaktive Kommunikation und Koordination über die "End of the bridge"-Phase seitens der Regulatoren verringern.

Das zentrale Fazit ist, dass wenn Brückentechnologien für den Übergang zu einer kohlenstoffarmen Wirtschaft genutzt werden sollen und der private Finanzsektor bei der Finanzierung eine wichtige Rolle spielen soll, die Phase des Brückenendes schon frühzeitig in die Planung und Kommunikation der Transformationsstrategie einbezogen wird. So können Investoren die langfristige Rentabilität und damit verbundene Risiken abschätzen und so die grundsätzliche Attraktivität entsprechender Vorhaben evaluieren. Möglich wäre hier, dass die Politik klare Klassifizierungskriterien und ein Label für Transformationsinvestitionen einführt.

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# 1.Introduction

Bridge technologies play an important role in creating resilience in situations of crisis, both in the public narrative as well as in political decision-making. While the narrative of bridge technologies has changed over the years, they once again play an important role in the current situation of the energy and climate crises. Even though there is no clear definition of what constitutes a bridge technology, the most commonly used definition in the climate context is that of "an economic activity for which there is no technologically and economically feasible low-carbon alternative [that] shall qualify as contributing substantially to climate change mitigation where it supports the transition to a climate-neutral economy"[1]. The most significant example in the current situation of crises are the terminals for liquid natural gas (LNG) along the German shore as a temporary solution to bridge towards a more diversified and more renewable energy mix. The floating LNG terminals are supposed to quickly provide infrastructure that is used for a short- to medium-term, while at the same time avoiding the need for long-term infrastructure construction. Here, the bridge technology narrative says that LNG terminals as bridge help to replace Russian pipeline gas, providing reliable energy with potentially lower emissions than alternatives such as coal until more renewable energy sources and more green hydrogen are available (Krapp, 2023). Thus, bridge technologies are supposed to be used only for an intermediate timeframe and the end of its usage is clear from its inception. However, this also leads to a series of questions around bridge technology infrastructure, from societal acceptance to regulation as well as bridge technologies' importance for the resilient transition towards a climate-neutral economy.

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[1] §10(2) in Regulation (EU) 2020/852

Typically, investments in infrastructure are attractive because of their long lifespan and relatively stable, secure returns (Oyedele, et al., 2013). Yet, bridge technology infrastructure is supposed to be used only for a transition period. A key question, thus, is how investors deal with this inherent conflict. At the same time, sustainable finance has been growing exponentially over the last years (FNG, 2022). With bridge technologies playing an important role for the mitigation of climate change risk, and the transition of the economy towards more climate-neutral solutions, it is important to understand how sustainable-oriented investors approach bridge technology and related infrastructure projects as investment opportunities, and how they think about the different timeline and risks associated with them. In order to be able to identify the considerations and issues around financing of and investing in bridge technologies, especially the perceived risks in financing decisions, we conducted a qualitative study. For this, we interviewed German asset managers who offer sustainable investment opportunities and invest in infrastructure projects, and triangulated the data from interviews of firms involved in constructing, and investing in, bridge technology infrastructure.

We conducted a total of 14 semi-structured interviews and analyzed the data inductively. Our analysis showed that investors focused on three sets of risks related to bridge technology investments. First, they identified risks connected to the bridge technology itself or the specific bridge technology project, specifically regulatory risks and risks related to the “end” of the bridge. Second, they were concerned about risks related to the classification of the financial investment product, specifically the difficulty of adequately classifying bridge technology investments in the existing classification schemes for sustainable investment products. Third, the asset managers identified risks related to the context of bridge technologies in general instead of a specific project, including reputational risks for their own organization.

These risks were reasons that hamper investments from the private sector in bridge technologies, notably in LNG context in Germany. Interviewees pointed to the circumstance that in other regions, particularly in the USA, these risks were less pronounced. The risks could be lowered through transparent and reliable transition pathways, in case of LNG for example regarding a future hydrogen market, through more specific criteria for the classification of transition investment products, and through early, science-based, and proactive communication and coordination about the “end of bridge” phase by the regulator.

We conclude that if bridge technologies are supposed to be used for the transition to a carbon-neutral economy, and if the private sector is supposed to play an important part in financing this, it will be necessary to include plans and communication about the end of the bridge at an early stage of the transition strategy. This enables investors to assess the long-term profitability and related risks of bridge technologies and, thus, their evaluation of the overall attractiveness of such investments. One option here would be to introduce a classification scheme and a related label for investments into transition products.

# 2. Literature review about sustainable investments in bridge technologies

Even though the idea of using technology as a bridge or only for a transition period has been around for decades, and has been used widely by policy makers, the definition of a bridge technology is vague. While bridge technologies are not strictly defined in legal terms, academic research usually refers to article 10(2) in Regulation

(EU) 2020/852 of the European Parliament for a definition. There, bridge technologies are defined in the climate context as "an economic activity for which there is no technologically and economically feasible low-carbon alternative [that] shall qualify as contributing substantially to climate change mitigation where it supports the transition to a climate-neutral economy consistent with a pathway to limit the temperature increase to 1,5 °C above pre industrial levels", with those activities having best-in-class greenhouse gas emissions while not hampering the development of better alternatives or leading to a lock-in of carbon-intensive assets. These last requirements make it difficult to evaluate whether something should truly be considered a transition or bridge technology. In addition, the narrative and thus the definition of bridge technologies has shifted several times in the last decades.

## 2.1. International narrative

The use of the term "bridge technologies", also known as "transition technologies", in the context of energy is closely linked to events of crisis and insecurity, and to a transition away from insecure energy supplies towards renewable and cleaner energy. The first-time the term "bridge technologies" emerged was in the 1970s, initially coined by Armory B. Lovins in his influential article about non-nuclear energy strategies (Lovins, 1976). To him, transitional or bridge technologies were technologies that use fossil fuels briefly to build a bridge to what he called energy income of 2025, defined by lower energy consumption and renewable energy supplies, using the term "transitional technologies" to describe a way of intelligent use of fossil fuels to buy time until renewable technologies became more scalable and affordable (Lovins, 1976). The essay was published in the context of energy insecurities, linked to the oil embargoes of 1970s and the growing anti-nuclear movement.

It was not until a decade later, in the late 1980s and early 1990s when natural gas started to be discussed as an alternative to coal in earnest, and it became a preferred “interim fuel” in the 2010s. As global warming entered the policy discourse driven by environmental movements around the world in the 1980ies, natural gas was said to be the “least harmful solution”, and it was argued by several clean energy advocates that it could be a transition away from fossil fuels (Hamilton, 1988; Gates, 1990; Howarth, 1995), as “the better option” compared to coal. The shale gas revolution in the US in 2008 then constituted the final breakthrough. A combination of technological applications of hydraulic fracturing and horizontal drilling allowed the US to significantly increase its production of oil and natural gas, which had a very important role as the country was recovering from recession in 2008. After the International Energy Agency proposed that the world was to enter the “golden age” of natural gas in 2011 in their widely publicized special report (IEA, 2013), this narrative was also embraced by Europe. In 2012, the EU Energy Commissioner, Günther Oettinger, stated that natural gas was expected to become “key for the energy future in Europe” (Hirschhausen, et al., 2018).

Today, natural gas often is discussed as an enabler of a hydrogen economy (Sánchez-Bastardo, et al., 2021; Dickel, 2020). The Russian invasion of Ukraine increased the concern regarding energy security because of the current dependency on gas and oil imported from Russia. Since liquefied natural gas (LNG) is not a climate-neutral energy carrier, LNG would act as a bridge to green hydrogen or ammonia with its assisting function in closing gaps or offering flexibility when there is high demand since fast built-up of terminals is needed for energy security. A potential solution to prevent carbon lock-in of the assets is to use LNG terminals and, converted, as climate-neutral energy carriers for liquid hydrogen (LH2) or ammonia (NH3). Currently, an extensive amount of research is being carried out regarding feasibility of the conversion of LNG terminals to ammonia and liquid hydrogen (Al-Kuwari & Schönfisch, 2021; Kar, et al., 2022; Khatiwada, et al., 2022). For example, research recently published by the Fraunhofer Institute for Systems and Innovation Research highlights that the feasibility of conversion highly depends on individual characteristics of the LNG infrastructure and location (Riemer, et al., 2022). Here, in case of Germany, investment needs, and especially the need to have reliable demand projections for infrastructure investments and planning security are highlighted as being of special importance (Riemer, et al., 2022).

## 2.2. National narrative in Germany

When applied to the German national context, the emergence of a bridge technology narrative can be traced back to a couple of years after Lovin's article, inspiring many environmentally oriented politicians, researchers, and intellectuals. In 1980, researchers who were trained by Lovins and from Öko-Institut published the first study on a transition path towards renewable energy in Germany: "Energie-Wende: Wachstum und Wohlstand ohne Erdöl und Uran" (Krause, et al., 1980). The study argued for phasing out nuclear energy while also rejecting oil in the transition. It proposed an energy mix in which increasing energy efficiency was supposed to phase out the reliance on nuclear energy as a bridge, while simultaneously increasing the share of renewable energy technologies. In the model outlined by Krause et. al (1980) during the phase-out of nuclear energy, oil and coal also continued to play a role. The portrayal of energy efficiency as a bridge leading to increasing use of renewables while phasing out oil and nuclear also demonstrates the bridging role in the transition.

As in the international narrative, the use of the term bridge technologies is also connected to a series of crises in the German national context. The 1986 Chernobyl nuclear accident could be seen as a starting point that nuclear power was increasingly considered not a safe option for energy production. The 1990s then marked the worldwide emergence of climate policies. Heavily influenced by the 1992 Earth Summit in Rio de Janeiro, Germany was one of the pioneer countries in developing a national climate policy that was aligned with environmental goals and later the 1997 Kyoto Protocol. From the 2000s onwards, climate initiatives initiated by Germany were complemented by gradual increases in renewables in the energy mix. In 2009, the new coalition agreement formed by CDU (Christian Democratic Union) clearly calls nuclear energy as a bridging technology stating "Nuclear energy is a bridging technology until the time when it can be reliably replaced by renewable energy. Without it we would not be able to meet our climate targets, enjoy tolerable energy prices and reduce our dependence on foreign energy sources." (CDU, et al., 2009). A year later, in 2010, as the government led by Angela Merkel set out plans under "Energiekonzept" that center around energy efficiency for a transition to a sustainable energy system by 2050, nuclear energy was again described as a bridging technology that "we need for a limited period" (FVEE, 2010). There was an ongoing discussion about whether nuclear should be a bridge or should have a role in the long-term energy mix until the 2011 Fukushima nuclear disaster marked a clear end to a potential role of nuclear power in the long-term energy mix. After the disaster, Merkel officially announced the "Energiewende" and later in 2013 the Grand Coalition agreed on the phase out of nuclear energy by 2022. This was very clear in Chancellor Angela

Merkel's statement that highlighted that nuclear energy as a bridge technology was coming to an end:

> The events in Japan teach us that things we consider impossible according to scientific criteria can nonetheless become reality. (. . .) We will suspend the recent decision to extend the lifetime of the German nuclear power plants. This is a moratorium that will last 3 months…The situation after the moratorium will be different than before. (. . .) We speak about nuclear energy as a "bridge technology," which means nothing other than that we are discontinuing the use of nuclear energy and want to ensure the German energy supply through the use of renewables as quickly as possible. The only honest response is to accelerate the path towards the age of renewable energies.
>
> (Chancellor Angela Merkel, televised press conference, March, 14, 2011, translated by Hirschhausen et al., 2018)

After the Russian invasion of Ukraine, the narrative of bridge technologies has been increasingly referring to natural gas as a transition fuel and LNG terminals as bridge technologies. Before that, there were two potential pathways discussed for natural gas: as a "backup" to ensure energy security and complement renewable energy sources, and as a "bridge" towards renewables by 2050 where all energy needs were envisioned to become renewable and demand for natural gas phased out entirely (Holz, et al., 2013; Neumann & Hirschhausen, 2015). Now, liquefied natural gas as well as (temporary) LNG terminals are called "bridge technologies". This has increasingly led to discussions and criticism, calling the new and planned LNG infrastructure projects a "bridge with no visible end" or plainly calling in question whether natural gas is a bridge at all (Henneberger, 2022).

Both nationally and internationally, the bridge technology narrative has been changing since it first entered public discourse. The commonality among all bridge technology narratives is the destination it leads to: renewable, secure, and clean energy supplies that provide more resilience in times of crisis. The duration of how long to travel on the bridge, and what will happen to the bridge once its end is near or reached remain unclear. At the same time, bridge technologies require infrastructures and investments, and the travel time across the bridge, as well as what happens at the end of it, are key questions for investors.

## 2.3. Characteristics of infrastructure financing

Bridge technologies in the context of energy can play an important part of the infrastructure landscape of a nation or continent. Infrastructure was therefore traditionally financed with public funds, with governments the main actors in infrastructure investments. However, deficits in government spending budgets and growing amounts of debt to GDP ratios resulted in insufficient investment spending (OECD, 2015). Such budgetary pressures meant alternative sources of financing were needed when it came to infrastructure development and institutional investors stepped in due to the long-term nature of the liabilities for many types of infrastructure investments (OECD, 2015). This has put strong pressure on institutional investors to narrow the investment gap and coincided with increasing investor appetite for investments into infrastructure as a way to diversify their portfolios after the financial crisis of 2007-2009 (Thierie & Moor, 2016; Inderst, 2020).

The typical characteristics of infrastructure projects are the reason for the increasing investor appetite to invest in these projects. Common characteristics associated with infrastructure projects are high barriers to entry, economies of scale, inelastic demand, and long periods of operation and therefore stable income (Panayiotou & Medda, 2014). These characteristics usually result in stable, long-run cash-flow for investors that is usually increasing along with inflation (Martin, 2010) and makes infrastructure investments attractive despite the high up-front investment needed for infrastructure projects. The literature identifies common investment characteristics of infrastructure investments as (1) secure and stable cash flows, (2) insensitivity to market conditions, (3) long asset life cycle and (4) inflation hedging properties. One distinctive feature of infrastructure investments is that they provide stable and predictable cash flows due to their long-term nature (Oyedele, et al., 2013). Their insensitivity in returns to the economic cycle makes them attractive for investors (Russ, et al., 2010). This allows investors to hedge against any downfalls in stock markets and fluctuations in interest rates. Infrastructure investments also tend to have low volatility by nature; several studies (Deutsche Bank, 2014; Oyedele, et al., 2013; Peng & Newell, 2007; Russ, et al., 2010) highlight that due to inelasticity in user demands, infrastructure investments have low volatility in cash flows. Another defining characteristic of infrastructure assets is their long-asset lifecycle. Infrastructure investments have a long life span of up to 60 years on average (Rickards, 2008). Finally, Russ et. al. (2010) show that inflation hedging characteristics of infrastructure investments is one of the major characteristics of infrastructure investments that drive investor appetite due to its liability-matching feature. The inflation-linked characteristics of infrastructure investments could potentially be useful for pension funds and insurance companies that have to match annuity type liabilities (Inderst, 2016).

Investments in infrastructure can happen through different methods and through a large variety of channels and investment vehicles but is not the focus of this study. Investment methods could be classified under 3 principal channels that have different financial and market characteristics: (1) Corporate investment (indirect), (2) Investment fund/vehicle (semi-direct) and (3) Project investments (direct). Direct investments are investments done directly to the infrastructure project through equity, debt, mezzanine, or public-private partnerships (PPPs), whereas semi-direct investments are done through pooled vehicles such as infrastructure venture capital (VC)/ private equity (PE) funds. Corporate investments include investing indirectly in infrastructure through publicly listed equity, corporate bonds, or funds. As well as the chosen channel, the asset category of the investments made also often entails inherent characteristics: debt typically signals a more secure tranche of investment, guaranteeing a lower level of yield whereas equity lies on the high-risk, high-reward tranche of investment and is often accompanied by greater volatility and risk. In relation to sustainable or social investing, research has shown that most investors used to prefer private-public partnership financing models (Wang & Ma, 2021), while infrastructure investments in general are moving more towards a separate asset class, instead of looking at infrastructure investments as investing in one specific asset (Gupta & Sharma, 2022).

## 2.4. Sustainable investing in infrastructure

Infrastructure investments have also started to play an increasingly important role for sustainable investors, since sustainable finance can be used as a lever to influence the “real” economy, and investment volumes have been increasing. Transitioning from an energy industry largely driven by fossil fuels to a low-carbon economy requires shifting considerable amounts of capital from non-renewable induced technologies to renewable technologies. An OECD (2017) study shows global infrastructure investment needs of USD 6.3 trillion per year over the period 2016-30 to support growth and development, without considering further climate action. Several studies (Woetzel, et al., 2016; OECD, 2016; IRENA, 2016; IRENA, 2020) show that traditional sources of capital will not be enough and additional funding sources are necessary to cover the green finance gap. Investors who do sustainable investing (SI), that is "investing that takes environmental, social, and governance (ESG) information into account" (Kölbel, et al., 2020) can therefore contribute to the achievement of green infrastructure goals. The volume and number of investment products in sustainable finance has been increasing every year (FNG, 2022). Thus, sustainable investors could significantly contribute to financing the transition of infrastructure and accelerate the energy transition.

When shifting from traditional to green infrastructure, investing in bridge technologies could help investors play a critical role in financing the energy transition towards renewable energies – even though traditional infrastructure characteristics don't apply to most bridge technologies! Currently, the academic literature on financing of bridge technologies by sustainable investors is barely existent, since even the literature on general infrastructure investing is still in its infancy (Gupta & Sharma, 2022; Kumari & Sharma, 2017). Still, there is an urgent need for a transition toward sustainable, energy-efficient, renewable energy that is climate-neutral and resilient. Bridge technologies are supposed to actively contribute to the transition to climate neutrality hence unlocking the capital needed for infrastructure is crucial. However, we don't know enough about investment decisions regarding bridge technologies and how specific characteristics and risks of bridge technologies factor in. Even though direct institutional investment activity in green infrastructure projects compared to more routine indirect investments (e.g., in corporate stocks and bonds) have been increasing, still investments continue to be minimal compared to the scale of institutional investors' assets and the magnitude of the investment gap (Studart &

Gallagher, 2018). Researchers, for long, have been asking for a comprehensive plan that “connects the dots" between private financial markets and sustainable infrastructure needs.

## 2.5. Risks in infrastructure financing

When the purpose of bridge technologies and characteristics of infrastructure investments are combined, some tensions quickly become apparent. The secure, steady, and long-term nature of traditional infrastructure investments do not align with dynamic nature of bridge technologies. Bridge technologies are expected to be converted to alternative solutions after fulfilling their purpose, whereas infrastructure investments are relatively long. It is not clear whether, when and how these timeframes match. The dimension of time also has resulting financial implications when it comes to returns: while infrastructure investments offer stable and steady cash flows, bridge technologies might not necessarily guarantee this due to the market being more sensitive to changes around them and the possible risks that may arise. Bridge technologies are also subject to risks which are not traditionally associated with infrastructure investments, such as climate risks, which are more relevant than ever today and have strong financial implications for investors.

While there is currently a lack of knowledge about the risks to financing bridge or transitional infrastructure projects and how these risks affect investments, past research has provided some insights into more general risks to infrastructure financing. These risks stem from the infrastructure projects themselves, the regulatory and political environment, and the larger, macroeconomic, or business environment. Risk from an infrastructure project could either arise from the asset itself, contract parties, or its exposure to the environment that it operates in, and the magnitude of risk varies. Examples are project complexity or risks in planning and constructing the project. Political and regulatory risks include risks arising from governmental actions and changes in regulations and policies, whereas macroeconomic and business risks are related to risks in broader environment such as inflation, real interest rates, exchange rate fluctuations, as well as changing demand and preferences.

In addition, the ongoing transition towards a more climate-neutral economy makes infrastructure investments prone to climate-related risks. Infrastructure projects usually have time horizons that span multiple decades, making climate related risks crucial to consider in the lifetime of the asset (In, et al., 2020 ). For example, physical risks of infrastructure projects include the risk of climate events such as extreme weather and chronic climate change, resulting damages to the physical structure and thus financial damage due to revenue interruptions, increased cost, or even entire write-offs (In, et al., 2022). Infrastructure investments could also be subject to transitional risks that stem from government policy, technological changes as well as changing consumer preferences. This could disrupt the volume of outputs and prices of the goods that an infrastructure asset produces (Ciccarelli & Marotta, 2021). In addition, new low-carbon solutions could serve as substitutes and could lead to asset stranding (Caldecott, 2018; Mercure, et al., 2018).

Some of the inherent risks in bridge technology infrastructure financing are the same as for “traditional” infrastructure projects, such as those related to the projects themselves. However, others are more prominent, or might simply differ. In addition, these risks are complex and interconnected, and we currently don’t understand which of these risks are seen to be material in investment decisions. This is especially true for those investors who focus on sustainable investment. We therefore focus on the following research question for this study:  How do the temporary nature and (perceived) risks related to bridging technologies affect investment decisions in the context of sustainable finance?

# 3. Methodology

To analyze how the timeframe and (perceived) risks associated with bridge technologies affect investment decisions by sustainable investors, we have conducted a qualitative study based on expert interviews. We did this in the context of Germany's plans to use liquefied natural gas (LNG) and floating storage and regasification units (FRSU) as bridge technologies towards an increase in renewable energy as well as an increase in capacity for blue and green hydrogen. Since this research aims to make recommendations to German policy makers, this setting was chosen with a focus on the German market and German investors. In this section, we will first provide a short overview over the research setting before we present the data collection and analysis.

## 3.1. Research setting: investing in German bridge technology

In order to tackle the recent energy crisis and prevent energy shortages, importing LNG via new, floating terminals in Germany was intended to contribute to greater resilience in the sense of a diversified energy supply as a transitional solution, without having to build long-term and lengthy infrastructures to be used only for a transitional period. Currently, 5 floating storage and regasification units (FSRU) and 3 fixed onshore terminals are planned or installed in Germany on behalf of the German Federal Government (BMWK, 2022). In addition, there is a private-sector FSRU project planned in Lubmin (ibid.). FSRU is defined as “a Liquefied Natural Gas (LNG) storage ship that has an onboard regassification plant capable of returning LNG back into gaseous state and then supplying it directly into the gas network” (AGL, 2017) whereas onshore terminals are land-based terminals. These nine projects are located in regions North Sea, Elbe River and Baltic Sea. Even though some of the projects were proposed in response to the current energy crisis, many were proposed prior to the outbreak of the war. There were also cases that a project has been cancelled and revived again after the outbreak of the war. Regardless of the proposal date, the outbreak of the war has accelerated the progression of these projects. In fact, the same is true for TES Wilhelmshaven LNG Terminal, cancelled in 2021 and revived in 2022 with the goal of developing a "green energy hub" at Germany's Wilhelmshaven port (Global Energy Monitor, 2023). The terminal is planned to import up to 5 million tons per annum of green hydrogen by 2045 (LNG Prime, 2022).

The LNG Acceleration Act, which was signed into law by the German parliament on 24 May 2022, underlines the urgency of building LNG terminals in Germany. According to the law, onshore and offshore LNG terminals are required in the interest of public energy security and must be built by accelerating various procedures (Bundesministerium der Justiz, 2022). These terminals have so far been paid for by the German state. However, the LNG facilities come at a high cost. The German Ministry of Economics now estimates the cost of floating LNG import terminals in the North and Baltic Seas at up to ten billion euro (Shiryaevskaya & Rogers, 2022). It is highly unlikely that such a multi-billion-euro investment could be financed by public funds alone, especially when onshore terminals are taken into account. This is underlined by the fact that the budget for a previously proposed sixth terminal ship in Hamburg was blocked now by the German parliament. This raises the fundamental question of under which conditions private investors might invest as well.

To answer this question, we analyze how investors perceived the risks of bridge technology investments, notably in the LNG and related infrastructure context.  and the investors' requirements and hurdles for potential investments. In the findings that follow, we ground the study's key constructs (risks, financial decisions, and recommendations), investigate what sustainable investors are concerned with when investing in bridge technologies, and explore how to make these investments more attractive.

## 3.2. Data collection

To study the perceptions of risks and the relation to the investment decisions regarding bridge technologies by investors, interviews were chosen as the main source of data, supplemented by websites and reports, predominantly for triangulation. Potential interviewees were chosen based on their investments in infrastructure as well as their aim to incorporate sustainability in their investment decisions – they all were "sustainable investors". We conducted a total of 14 semi-structured interviews within a 5-week period in November and early December 2022 (see Table 1). 11 of the interviews were conducted with representatives of asset management organizations (AM1-11) of different sizes, different levels of sustainable investing, as well as in different asset classes for this study. In addition to the interviews with the asset managers, we also conducted 3 interviews with firms (F1-3) involved in building or running the planned LNG Terminals. They therefore invested directly in them. While we talked about financing and investing with these firms, we ultimately used these 3 interviews for background information and triangulation reasons. In general, each interview covered three main topics: (1) risks associated with bridge technology, (2) time horizon, and (3) recommendations to the policy makers. The interviews were conducted via Zoom or MS Teams and lasted from thirty minutes to one hour per interview. All interviews were recorded and then transcribed, resulting in a total of 147 pages of interview transcripts. While the sample is small, our goal was not to reach saturation, but to gain a rich understanding of the issues surrounding bridge technologies and bridge technology investments, to identify future questions and how to best address these issues.

We complemented this data with documents and news reports about the planned LNG terminals as well as information about investment approaches from the interviewee's corporate websites.

**Table 1**

**Overview of data sources**

| Type of Organization | Position | Working years in this company |
|---|---|---|
| Asset Management | Founder & Managing Partner (AM1) | 5 |
| | Portfolio Manager (AM2) | 4 |
| | Senior Advisor to the Board (AM3) | 1 |
| | Co-Head of Infrastructure Expertise (AM4) | 4 |
| | Head of Energy Transition (AM5) | 4 |
| | ESG Officer (AM6) | 3 |
| | Managing Director (AM7) | 11 |
| | Chief Investment Officer for Infrastructure (AM8) | 11 |
| | Chief Investment Officer und Managing Partner (AM9) | 12 |
| | Managing Director for Illiquid Assets (AM10) | 22 |
| | Director Investment Team (AM11) | 1 |
| Gas Transport | Managing Director (F1) | 14 |
| | Manager Operations (F2) | 24 |
| | Head of Sustainability in Financial Media Communication (F3) | 6 |

## 3.3. Data analysis

We relied upon grounded theory methods to inductively analyze our data (Glaser & Strauss, 2009; Gioia, et al., 2013). A classic grounded theory process was followed: from a low-level concept to a medium-level concept and further to a high-level concept, which includes advanced coding and theoretical foundation (Birks & Mills, 2015). Our main interest was to understand whether and under which circumstances sustainable investors would be willing to invest in bridge technologies, and how perceived risks associated with bridge technology projects factored into these investment decisions. We finally asked how these risks could be minimized. Answering these questions guided coding into first order codes, which happened through comparison and circling through our codes to identify similar and recurring codes. Thus, following Bernard, et al. (2016), the interviews were fragmented in the first step. All quotes, that potentially could be interesting for the research, were highlighted in the text. Each highlighted quote was marked with a note (memo), explaining why it was interesting. A memo is a short remark that helps researchers to ensure that the key point will not be forgotten (Harding, 2019). The quotes were then merged into 24 first-order categories, such as "asset runtime risk", "pressure from NGOs", "long-term profitability concerns with bridge technologies".

In the next step we developed second-order themes by identifying common themes among the first order categories. By cycling through the first-order categories and comparing them, we identified recurring codes that we collapsed into 11 second-order themes. So, for example "concern about own organization's ESG goals" and "concern that LNG might hinder the energy transition" were summarized to "environmental risks". For this, we circled between the data and the theoretical knowledge about infrastructure investments as well as sustainable investing from the literature.

Finally, we formed aggregate dimensions by connecting intertwining second-order themes. For example, the second-order themes “environmental risks” and “reputational risks” were collapsed into “contextual risks”. This process led to seven aggregate dimensions that constitute the basis of our model. Specifically, these dimensions correspond to three levels: the risks related to bridge technologies, how they affected the financial decisions, and measures and recommendations that could potentially minimize those risks. The provisional model was refined over several iterations - returning to the data throughout - until a final model was established.

# 4. Findings

Our findings show how sustainable investors perceived the risks in bridge technologies for investing decisions, their consequent investment decisions and a series of actions that can mitigate these risks. The model is summarized in Figure 2 and is organized around the seven aggregate dimensions that emerged from our grounded theory building, as summarized in Figure 1.

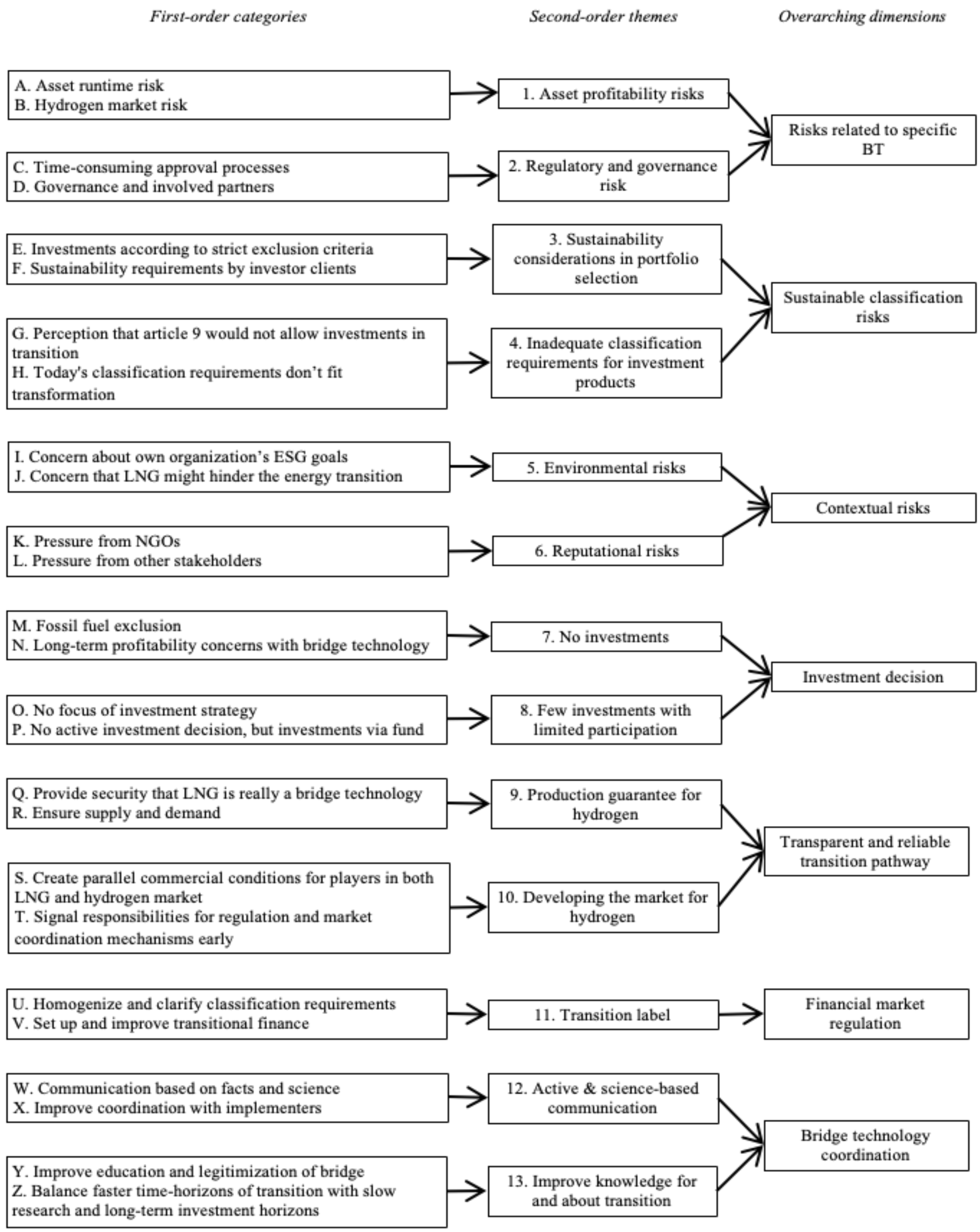


*Figure 1- Data structure*

As can be seen in Figure 2, our model begins with an evaluation of the perceived risks. During this process three main types of risks were identified – risks related to the specific bridge technology, risks related to sustainable classification for the investment product, and contextual risks that affect the organization of the investor in relation to financing a bridge technology. The model then delineates the response to these risks, which is labeled as financial decision. The final part of the model shows the actions which can help mitigate the perceived risks in the eyes of interviewed investors. These mitigation strategies are labeled as hydrogen market regulation, financial market regulation and bridge technology coordination. The main idea behind such a listing of risk minimizing activities is that each of these activities helps to manage the above-mentioned risks. For example, hydrogen market regulation helps to decrease the risks related to bridge technology or financial market regulation helps to decrease the risks related to sustainable classification requirements, etc.

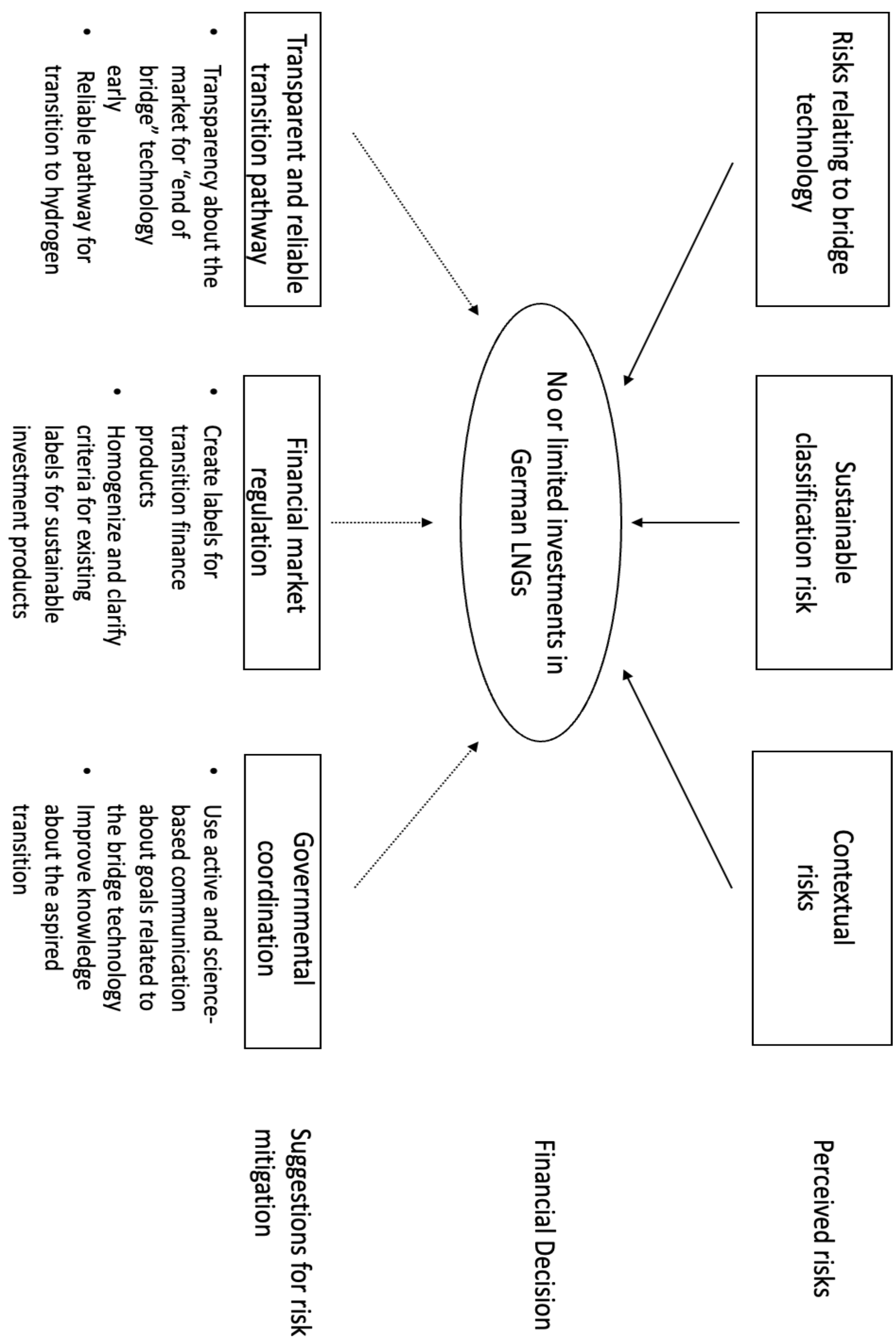


*Figure 2. Model of perceived risks and financial decisions as well as suggestions for risk mitigation strategies*

## 4.1. Perceived risks associated with bridge technologies

In this section, all the risks identified by investors are illustrated and explained. These risks were perceived by the investors as significant to impact the decision-making around investments in bridge technologies. The risks related to three dimensions: the specific bridge technology, the risk of a sustainable classification and the contextual risks.

### 4.1.1. Risks related to specific bridging technologies

Risks related to specific bridging technologies are those that have to do with the infrastructure project, such as the nature of the project, the technology, its's regulation and approval, etc. Due to our research context and the prominence of LNG terminals as bridge towards green hydrogen as energy supply, the interviewees spoke predominantly about risks associated with LNG terminals as bridge technology, but also brought up some more general risks. The risks we identified could be related to the profitability of the specific asset as well as aspects of regulation and approval of the bridge technology.

***Asset profitability risks.*** The investors in our sample were exclusively sustainable investors, for whom sustainability means investing in the long term (15-25 years on average). On this basis, the main risk identified was that of the asset runtime risk:

> If you start building an LNG terminal now, and at the same time it's said that a bridging technology will be phased out after ten years, someone has to explain to me why I should invest billions there (AM10).

Thus, in the case of LNG terminals, these long-term investors could not be sure how long such an asset would still be needed in Germany. How long would the asset be able to operate profitably? These and similar questions were the first to be asked by sustainable investors because the profitability of an investment was closely linked to its lifetime. As the word “bridge” implies, this technology will only be used for a transitional period. Therefore, investors needed to ensure they could not only earn their initial investment, but also a risk-adjusted return before the technology would not be used any more.

In this study, the LNG terminals were considered with the perspective of shifting to green hydrogen. For this reason, the investors not only talked about profitability considerations during its use as LNG terminal, but also at the end of the technology’s use as a bridge, when it was supposed to be converted to hydrogen terminals. This risk was labeled as hydrogen market risk, which results from the lack of knowledge about a future market for green hydrogen. This was a financial risk that investors faced due to a lack of security about supply and demand for hydrogen. The investors questioned whether sufficient customers would commit to actually buying green hydrogen, which does not yet exist in sufficient supply, and currently is still much more expensive than natural gas. The managing director of a global investment firm described this as difficult „because investments come at the beginning. And there's actually no off-take security, and that's why there's actually no long-term investor who can then be willing to spend the one-time investment amount today" (AM7). This risk was further exacerbated because the clients of the interviewed investors were mainly insurance companies and pension funds that wanted to invest in a long-term sustainable product, and they were not willing to take high risks. If the asset managers invested in the LNG terminals with the perspective of switching to hydrogen and then had difficulties down the lane to make that switch, they explained that it would be highly problematic. Thus, this market risk about the technology that was supposed to follow the bridge technology already caused profitability risks today.

***Regulatory and governance risk.*** Beyond profitability of the bridge technology project, the investors also identified risks to bridge technology projects that were related to regulation, as well as to governance of a transition project. First, investors feared a risk of time-consuming administrative processes to get bridging technologies approved and running. A managing director described it as follows:

> Then on the individual project basis, these procedures just take super long. Getting through these different stages first of all somehow, like local application and then possibly European funding (AM10).

The companies that build infrastructure projects had to go through various assessments, such as complete environmental impact assessments, to receive permits. And accordingly, these approval processes were long, and further extended by potential lawsuits for environmental protection reasons. Therefore, investors feared that they would have to wait for projects to be operational and for returns to start coming in.

The second risk related to regulation was that of governance responsibilities of the end-of-bridge technology. Here, insecurities about involved partners and especially the role of the state played a major role in the investors' considerations. This included questions about the complexity of a governance construct:

> For us, the other investing parties, or ownership structures, thus the governance in a sense, that's a central topic that has to be looked at for every transaction in a very early stage. Many investments are declined right there because the complexity in such a consortium for example, is too high and because there are too many different interests colliding in it (AM11).

This asset manager continued to stress that a central question was that of whether the bridge technology, or the more sustainable technology at the end of the bridge, was supposed to be predominantly financed and operated by the state or a private organization. Moreover, investors knew that transitioning infrastructure for natural gas to the use with hydrogen would require massive investments and explained that it was difficult to launch the market without government subsidies, but that there was still a lot of insecurity around subsidies vs direct government involvement in the transition, or other long-term guarantees by the state.

### 4.1.2. Sustainable classification risk

The sustainable classification risk refers to considerations related to the investment product and therefore is related to the investor and their underlying investment clients. Nowadays, several different sustainability disclosure standards exist or are being developed (e.g., EU Taxonomy, Sustainable Finance Disclosure Regulation SFDR). These standards and regulations intend to improve transparency in the market for sustainable investments and are supposed to make it easier for clients to understand whether their investment should be considered to be sustainable. This means that the standards and regulations often determine how sustainability considerations are integrated in the selection of portfolio assets. Due to this, the asset manages we interviewed were not sure how to incorporate bridge technologies into sustainable investments, and the investors complained that current classification schemes for sustainable investments did not fit with investments into the transition towards climate-neutrality.

***Sustainability considerations in portfolio selection.*** Investors have different strategies of how they integrate sustainability considerations into their portfolio selection. Many investors explained that they could not invest in natural gas, or in oil and gas companies, even if the investment was in a bridge technology, due to their sustainability exclusion criteria that they applied to their portfolio. Other investors refer to what their investment clients prefer and that they have sustainability assessments for investments due to their clients' preferences:

> The topic of sustainability is really important for our investors, increasingly important, and thus, logically, the topic plays an important role in our investment decisions (AM9).

***Inadequate classification requirements for investment products***. Some investors preferred to be very strict in their investments and chose investments that could be classified under existing sustainability criteria, such as article 8 or 9 of the EU disclosure regulation SFDR (Sustainable Financial Disclosure Regulation). Article 9 SFDR represents – at least this is the common perception in financial markets - "dark green" investment products that have strict requirements to satisfy environmental sustainability criteria. One partner of a boutique investment firm explained his investment decisions:

> Does this company report impact data [according to article 9]? If not, then we will not hold it. Are we getting necessary data? If they are not doing that, then we will not hold such an asset (AM1).

At the same time, some investment managers interviewed believed that Articles 8 and 9 would in principle allow investment in LNG terminals because the investments in bridging technologies could be seen as part of transitional finance. Thus, the classification scheme and labels seemed to be confusing and required interpretation.

However, the interviewed majority thought that today's sustainability classifications did not really direct money to transition investments since they required investments in already “green” assets, but acknowledged the need to invest in the transition:

> I don’t help to get to net zero when I only invest in renewable energies or green bonds now. I have to really focus on industry sectors that are still dirty and need to help those to get clean. So, the transitional finance is really important (AM8).

The majority of investors evaluated existing criteria as requirements to invest in already “green” assets, and therefore not for transition products, even though they saw the need to invest into the transition.

### 4.1.3. Contextual risks

Our analysis of the data resulted in a third category of risk perceived by sustainable asset managers in connection with investments into bridge technologies, which we called contextual risks. These risks stem from the environment of the bridge technology and affect the asset manager’s organization. Theses risk increased the organization’s environmental risk or reputational risks.

***Environmental risks.*** Investors were concerned with high carbon dioxide (CO2) and methane (CH4) emissions that are released into the environment because of natural gas. Carbon dioxide enters the atmosphere through burning natural gas and methane is emitted during the production and transport of natural gas. Since some investors had clearly defined goals for their own organizations about how to get to net-zero and when to achieve these goals (some as early as 2025), investments in still dirty technologies such as the LNG terminals did not fit into their overall investment strategy. A Chief Investment Officer for Infrastructure said that LNG "takes an extreme amount of energy to liquefy [...] and then re-gasify it. So, it's extremely dirty, unless you do it with renewables" (AM8).

In addition, several sustainable investors did not only integrate sustainability concerns in their investments because of client demands but were very serious about creating positive change and avoiding any kind of environmental harm. These investors expressed concern that LNG as a bridge could hinder the energy transition. The investors criticize the governmental decision to put billions in the natural gas-driven LNG and prefer to promote investments in renewable energies. They believe that "if we really invested in renewable energies now, or invested more in storage and decentralized networks, etc., then the transition could succeed" (AM1). Other investors were concerned that Germany would not have enough wind and solar capacities to produce green hydrogen in sufficient amounts and therefore were afraid that the use of LNG would be drastically extended to provide the security of energy supply. Thus, this would put the environmental goals of the investor’s own organization at risk.

***Reputational risks.*** Reputational risk was a common theme in the interviews. The interviewees said that the pressure from NGOs and other stakeholders had a big influence on their financial decision making. Many investors were convinced that if they were to invest in LNG infrastructure, NGOs would become “a major headache” (F1). If they were to be called out by NGOs, this would also increase other risks, including violent action such as sabotage.

In addition, other stakeholders such as communities and cities affected by the infrastructure should also be considered, as one Chief Investment Officer explained:

> Because it is embedded in a political dynamic. They are embedded in a social dynamic, so you can get your asset in wonderfully, but then you are also tied into this community for the next 20 or 30 years and then you can

> no longer get your investment out. That's why, for us, it's absolutely essential to think about such things in advance and to include them in the risk assessment (AM9).

## 4.2. Investment decision making

As a consequence of the risks, investors explained their decisions of whether they would invest in bridge technologies. While most explained that the combination of the perceived risks meant that they preferred to not invest in bridge technologies in Germany and instead preferred to focus on already "green" investments, others had invested in bridge technologies including LNG terminals in other geographic areas. Still, these investments into the transition currently did not play a significant role in their portfolios, despite them acknowledging the importance of the transition.

***No investments.*** There were two main reasons why investors excluded Investments in German LNG Terminals from their portfolios, namely a rejection of anything that was considered "dirty", especially fossil fuels, or a hesitancy to invest in bridge technologies due to limited profitability. First, the exclusion was based on the idea that during the burning process and the transportation of fossil fuel, i.e., natural gas in this case, it produces a lot of GHG, both CO2 as well as Methane (CH4) emissions. Thus, a lot of sustainable investment managers saw the "do no significant harm" criterion as being violated. Moreover, they believed that financing natural gas driven LNGs could threaten the efforts to consume less fossil fuel-based energy. Therefore, they preferred to invest and develop renewable energies. At the same time, they admitted that security of energy supply in Germany remained a priority, and natural gas would still be needed to achieve that. Nonetheless, most investors that aimed to offer sustainable investment products reject investments in anything related to fossil fuels:

> If we didn't have natural gas, it wouldn't be warm in my apartment at home either. It's a necessity. We're going to have to keep using it because we don't have enough green energy available right now. Yes, but we are actually radically eliminating anything that's fossil fuels, I don't have anything in the portfolio there (AM2).

In general, these investors who refused to invest in fossil fuels were very hesitant to invest in bridge technologies in general and preferred to invest only in renewable energies and already “green” investments.

The second reason why investors made the decision not invest in German LNG infrastructure was that they were not willing to invest in a technology that was seen as still dirty, but at the same time a transition technology. While most investors were not willing to invest in fossil fuel infrastructure at all, those who were willing to invest in infrastructure that was still considered as dirty, were hesitant to do that for a short transition period only. They perceived LNG in Germany as much riskier than Investments in the same LNG infrastructure in other geographical and regulatory environments, especially the U.S. They perceived LNG infrastructure in the US as a long-term energy solution, compared to the bridging function it had in Germany:

> Germany clearly sees LNG as a transitional technology. Germany ultimately wants to go somewhere else with renewable energies, and if I simply put the two countries next to each other, the USA and Germany, then LNG will probably end sooner in Germany than in the USA (AM9).

In addition, they saw it as an advantage that terminals were also used for export in the US, whereas in Germany it would only be used for LNG imports, and thus had limited potential for significant long-term profitability.

***Few investments with limited participation.*** Some asset managers were willing to invest in bridge technologies and were invested in German LNG infrastructure. Still, they felt that bridge technology investments were not specifically wanted, and transition investments were not a big part of their portfolio.

> Well, yes, and we do invest in that. But that's not a big focus now, so that we say bridge technology must or should have a certain share of the portfolio, that's part of the transition consideration overall (AM3).

Generally, the interviewees were not enthusiastic about investing in bridge technologies. They explained that investing in the transition and in bridge technologies was not an attractive investment possibility because they required more due diligence, since the possibility and risks related to the end of life and end of the bridge also required considerations prior to the investment. While those investors stressed that it was important to them to invest in the transition, and that infrastructure investments were becoming more important, their current holdings of bridge technologies happened due to being invested in infrastructure funds, instead of holding direct investments. This meant that they often did not make an active decision to invest in bridge technologies, but that such a technology was simply included in a fund they invested in. The main reason for that was a better risk diversification.

> It would then be more of an option for our indirect investments, because here they can mix in a small quota in a niche fund, because they have a very large portfolio, and then they can manage this risk diversification better. (...) but for direct investments, I don't see that yet (AM11).

In summary, while sustainable investors saw the need for investments into the transition, and also acknowledged the need for LNG infrastructure for energy security, they either refused to invest for sustainability reasons or for profitability risk, or they were hesitant due to the risks they still saw as very significant. Therefore, in the next step, we asked how the identified risks could be mitigated.

## 4.3. Recommendations to help reduce risk-related consequence

Since sustainable investors were hesitant to invest in bridge technologies due to the identified risks, we also asked them about recommendations on how to minimize the risks and, potentially, to change a negative financing decision into a positive one. The risk mitigation options were sorted into three aggregate dimensions: hydrogen market regulation, financial market regulation and governmental coordination.

### 4.3.1. Transparent and reliable transition pathway

The bridge technology that the investors in our study focused on was that of LNG and its transition function towards hydrogen. Therefore, the recommendations to mitigate risks related specifically to the bridge technology of LNG focused on the hydrogen market and its need for a transparent and reliable transition pathway. Specifically, it was suggested to create production guarantees for hydrogen as early as possible, and to actively develop the market for hydrogen to minimize market risks, provide financing structures and define market control.

***Creating production guarantees for hydrogen.*** To minimize the risks specific to the bridge technology, the investors asked for more clarity about the availability of the “end of the bridge” technology, thus in this case hydrogen. Some investors were still not convinced that the end of the bridge was viable at all, whereas the concern of others was about a match of supply and demand.

The partner from the small investment boutique mentioned that it was important for him to see the production of green hydrogen at an industrial level first, even in small quantities, so that he could be sure it's possible to produce green hydrogen at all. To do this, he suggested developing a social "flagship project" to show people: "It can really be done and we're really doing it. And that would be a flagship project that I would strongly endorse (AM1). In addition, there was doubt that LNG would only be a bridge, and that the transition would work in the way it was currently foreshadowed, since there were barely any guarantees:

> So, there is simply a lack of this linkage where you say you really use it as a bridge technology, and I'm really a bit cautious about whether you could really confirm all of that already, that this is also a bridge that really has a fixed end point. (...). Having more certainty about this would actually help our investors to be able to make that risk assessment as well (AM11).

Therefore, the asset managers would prefer to have more long-term transparency and reliability of transition pathways, to guarantee that a “green transition” investment is actually an investment that contributes to the transition of the economy, and not secretly into a “dirty” project or infrastructure.

A second recommendation to mitigate risks related to the bridge technology itself concerned the match of supply and demand at the end of the lifespan of the bridge technology and during the uptake of the technology it was bridging to. Here, the investors especially recommended off-take guarantees. Some investment managers suggested guarantees by the government for a certain amount of off-take for a certain period of time, as a reliable basis for risk and profit calculation. “Something like this would really help us: I just sell to the state, the hydrogen that was produced, and I don’t have to deal with every single off-taker individually” (AM5). Investors can then calculate returns and risk: “OK, they're going to buy so and so much at this price, so I've already got guaranteed revenues as a government guarantee, or I've got a really strong player in this context who's going to buy it” (AM10). One investor suggested that these guarantees did not have to come directly from government, but that it would be helpful to facilitate these guarantees through the future major consumers for hydrogen, such as companies with significant energy needs as another strong and valid signal for stable demand at the end of the transition period: “If [some major chemical company] says it will buy hydrogen for a certain number of years, then investors have a basis for calculation” (AM10). These guarantees would also ensure that the bridge technology would indeed only be used for a transition period and that investments into these kinds of infrastructure would indeed contribute to the transition towards net-zero.

***Developing the market for hydrogen.*** A second a response to project-specific risks was to actively develop the market for hydrogen. This includes commercial conditions for the end-of-bridge technology that ideally would be like those that are currently known, in order to avoid the need for the development of new skills, as well as clarity about who would have responsibility for regulation and coordination of the new market.

The need for similar regulation was based on the need to scale up the market for hydrogen in parallel to minimizing the market for natural gas. The investors assumed that the existence of both technologies, and the plans to convert existing infrastructure for natural gas towards the use for hydrogen would mean that many of the operators and players in the new market would be similar to those who are operating in the existing natural gas market. Therefore, they already have capacities to deal with the regulation and conditions in the natural gas market. The investors pointed out that it would not be efficient to create an entire parallel infrastructure and therefore parallel skills to deal with a different set of conditions, and that the market conditions should therefore be similar:

> Converting a hydrogen network in parallel to natural gas is nonsense; instead, convert gradually. But it will only work if there are similar commercial conditions for hydrogen as for natural gas (F2).

But it's not just that the commercial conditions need to be created in parallel to the existing or bridge technology to guarantee a seamless transition, but also to signal early the institutional responsibility for regulating and coordinating the new market. One interviewee suggested that a respected institution, e.g. KfW, should guarantee that the conversion to green hydrogen will take place. With such a guarantee, he would have a "more or less good" understanding of the cost development and he could then also price in the volatility in the new market, thus the uncertainty in the investment for both the bridge but also the developing market at the end of the transition would be reduced (AM8).

Similarly, the investors required that, regulation and coordination in the new market was clear alongside the regulation of the bridge. Currently, the natural gas market is run by the private sector but regulated by the government. In other words, they are regulated companies, meaning they have assets and are allowed to earn a percentage under this regulatory system. This percentage is set by the Federal Network Agency and is based on the interest rate level on the capital market. As a result, the prices are always regulated by the government. Investors and operators explained that If the regulation was purely private, and a shortage of supplies appeared somewhere, the tariffs could easily be tripled (F2). Thus, they explained:

> And in my opinion, this regulated regime should also be applied to hydrogen networks. That's where the state comes in because the state has to maintain the regulatory conditions. So, the state sets the regulatory conditions by law. The Federal Network Agency implements them (F2).

Part of this regulation, some suggested, was also the coordination of supply and demand. The investor compared this to the highway context. The original highway toll models were volume models, which meant one was paid for every truck on the highway. In addition, there are availability models in which it doesn't matter how many cars or trucks use the highway. The underlying desire of these suggestions is the requirement by investors to reduce uncertainty around payments and returns both from the bridge technology, but also from the intended use of the infrastructure after the transition. The most common suggestions to help guarantee this, in addition to regulation of the market, were subsidies as well as financing models through public-private partnerships and blended finance structures so that the government also had an interest in guaranteeing a profitable and timely transition of the technologies.

### 4.3.2. Financial market regulation

In order to mitigate risks related to the financial investment products and classification of these products as sustainable investments, the sustainable investors said that classification criteria need to be homogenized and more clear, with less room for interpretation. Also, the investors explained that transition investments needed to be labelled more clearly.

***Classification scheme and label.*** The sustainable investors asked for more homogenization of the classification standards to reduce confusion and allow less room for interpretation to prevent greenwashing.

> Therefore, the aim is to achieve homogenization. And the same applies to the EU taxonomy and, ultimately, the EU's efforts to achieve standardization to minimize or perhaps prevent greenwashing (AM9).

In this context, reliable labels become increasingly important for financing the transition. Separate transition labels would allow investments in bridging infrastructure without further interpretation and without fear of being caught on the greenwashing. To get to net-zero, asset management firms must invest in transitional finance. They agreed that net-zero could not be achieved without bridge technologies, but that current labels were not sufficient: “Sometimes I can understand well where the regulation [for these labels] is stemming from, but it sometimes does not fit everything (AM6). Instead, this investor criticised that even the classification as an article 9, SFDR investment product, which was seen as adhering to the strictest criteria was not working. This investor argued that the current labels used criteria that fit behaviours as if what should be achieved in 2050 were already achieved, and less about how investments could generate and support real-world changes towards these long-term goals now.

Thus, the interviewees in our study asked for fostering efforts in the context of transitional finance:

> "And that, for me, is transitional finance. (...). I actually have to focus on industries that are dirty and help them get clean" (AM8).

### 4.3.3. Bridge technology coordination

Finally, we found that the asset managers recommended to minimize contextual risks of bridge technologies that were not specific to one technology or project as governmental coordination but affected their organizations as sustainable investors in general. The leading thought behind this category is that these contextual risks were situated in the wider system in which both the bridge technologies as well as the eventual ends of the bride were embedded. Therefore, measures to minimize these contextual risks needed to be coordinated with the regulation of the bridge technology as well as the regulation of the investment in the financial market, since both the actual bridge technology, as well as the investment in a bridge were inseparably intertwined with these contextual issues.

***Active & science-based communication.*** The asset managers were firmly convinced that there was a great deal of idealism in politics when it came to issues related to the energy transition, even if this idealism was well-intentioned. Instead, they argued for a more scientific, fact-based decision making.

> Work more with facts and science. We should work hand in hand to tackle the energy issue in a really effective and forward-looking way. You always have to look at what is possible and what the consequences will be. I often think that the political discourse is very idealistic and therefore not always effective (AM4).

The investors further argued that more communication about these facts and the science behind them was needed, and better coordination between politicians and those implementing the goals.

***Improve knowledge for and about transition***. The investors also cautioned that the knowledge about the transition was not sufficient and should be improved. This related both to knowledge in the general public, and also scientific knowledge and research about potential solutions. In relation to the knowledge within society, one investor had the impression that most people would not be able to clearly state where the energy they were using came from, let alone that they understood the complexity behind it. Therefore, they lacked understanding of the problems of decarbonizing the energy sector.

> So, I think politics has a duty to educate the public, to explain what the consequences of certain decisions are, and then to actually find the right way in a democratic discourse, not only from a scientific point of view, but also with broad public support (AM4).

Yet, simply communicating complexities better and educating society about decarbonizing the energy sector would not be enough. And while the investors acknowledged that there were technological solutions that were ready-to-use, they also cautioned that these solutions could still be improved.

> Bridge technologies are supposed to have an effect. They have to support society, the economy really, just like their name states, in bridging from widespread fossil fuels to non-fossil energy or production modes. And all of that is connected one-to-one with research and development and optimizing these new forms of energy (AM4).

Therefore, more research in identifying and developing new solutions was needed: “Innovation requires time. The solutions that we have are good, but not perfect yet” (AM4). Here, the requirements of a fast transition needed to be balanced with slow research and development cycles as well as sustainability investments with long time-horizons.

# 5. Conclusion

The transition towards a climate-neutral economy will be challenging, and in some areas, it will be necessary to bridge between the current (in some areas rather) “dirty” state and a future clean state through the use of bridge technologies. In this study, we explored how sustainable investors approach investments into such bridge technologies. In our case, the investors particularly talked about investment in LNG infrastructure in Germany as a bridge technology, though some also mentioned that carbon dioxide removal might be considered a bridge technology for certain sectors or industries as well.

In our qualitative study we focused on German asset managers that take social and environmental issues into account when investing as well as additional interviewees that are involved in building LNG infrastructure. The interviewees identified risks related to a particular bridge technology, in our case LNG infrastructure, risks that stemmed from the classification of the investment into bridge technologies, and risks to the own organizations mainly in the reputational context. These risks often led to a low appetite for investing in bridge technologies. However, the asset managers also recommended that these risks could be minimized by providing a more transparent and reliable path forward for the “end of bridge” phase of the technology. In the LNG case this relates to the future utilization of hydrogen. Moreover, a classification scheme and related label for transition finance products could help increase the attractiveness of bridge technology investments, and better communication and science-based long-term decision making would help minimize risks in the context of the bridge technology.

With this study, we first contribute to a better understanding of how financial market actors perceive the risks associated with bridge technologies and how these are reflected in investments that support the transition of the economy. We show that especially because the bridge technology itself is supposed to be used only for a limited time, the investment considerations reach beyond the bridge technology's expected lifespan. When evaluating an investment into a bridge technology, the investors approached the end-of-life technology with just about the same due diligence as they approached the bridge, and in addition they raised questions about whether the bridge would indeed end and lead to the goal that was being envisioned now. Thus, if regulators aim to encourage investments into technologies or infrastructure that are supposed to be just a temporary step in the transition, it is necessary to consider transparency on the future market conditions as well as a reliable transition path beyond the bridge. That's because investments into bridge technologies, especially in infrastructure, require investments now while the "green" benefits will only be reaped in the long-term.

Second, we contribute to an understanding of how sustainable asset managers approach the creation of investment products that are supposed to help the transition, without being fully "green" yet. While they acknowledged that these investments into the transitions were necessary, instead of investing predominantly in (already) green investments, or, even worse, engage in greenwashing, they felt that these transition finance products currently were (a) not wanted and (b) hard to classify within existing classification schemes. In addition, they feared that these products would potentially not be aligned with their own organization's decarbonization ambitions. Therefore, if it is the declared intention that private investors shall actively contribute to financing the transition, the interviewed investors recommended the creation of a classification scheme and a related label for transition finance investment products. At the same time, it needs to be assured that bridge technologies, especially those that are still utilizing fossil fuel-based resources, will indeed be phased out in the planned timeframe.

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# Appendix

**Table 2**

**Representative quotes derived from interviews**

| **Second-Order Themes and First-Order Categories** | **Representative Quotes** |
| --- | --- |
| **Overarching Dimension: Risks related to specific BT** | |
| 1. Asset profitability risks | |
| A. Asset runtime risk | A1. Those are obviously the primary risks that I look at, do I have the refinancing risks and, if so, is that an asset that will still be needed in 5, 10 or 15 years? (AM8).<br>A2. (...) Or at least we don't want to invest in something where we know for sure that it won't be relevant in ten years' time and that we won't find a buyer. And therefore, we probably won't get the return we expect (AM9). |
| B. Hydrogen market risk | B1. Bringing producers and consumers together. Who produces, who brings in hydrogen and where are the customers? How do they come together? Who is willing to invest money as a customer, which is much more expensive than natural gas, and to commit over a long period of time due to large investment volumes? (F2). |

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| | B2. So, the risk is there, of course, because we have a chicken-and-egg problem, the market is not there yet and we change our system accordingly. If we were to do that earlier, then we might have a system that we are offering to the market that is not being used. And then, of course, there would be a big risk (F1). |
| 2. Regulatory and governance risk | |
| C. Time-consuming approval processes | C1. So, you can now see in Wilhelmshaven how quickly the terminal can be built by speeding up the various processes, if you want to do so (F3).<br>C2. We have to go through the process a hundred times. And that takes away a lot of the benefits, because the institutional investors say, how long does it take you to do a project like this? I say two years, he says crazy. It could actually be done in three months (AM5). |
| D. Governance and involved parties | D1. Who are the parties involved? Public or private? How is it going to be financed, or who is going to finance it? (AM11).<br>D2. On the producer side, I think it makes sense to organise this privately, although it will be difficult to launch the market without subsidies. Huge investments are needed here too (F2). |

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| **Overarching Dimension: Sustainable classification risk** | |
| 3. Sustainability considerations in portfolio selection | |
| E. Investments according to strict exclusion criteria | E1. We now have very, very specific KPIs in our financing on how to get to net zero. It has to be Paris-compliant and it cannot be achieved with LNG (AM8).<br>E2. These are ESG criteria that we set ourselves six or seven years ago. They are very much based on the exclusion criteria of the "Umweltzeichen 49" in Austria and the "FNG-Siegel" in Germany. And then there are some additional exclusion criteria that were important to us that are mixed in (AM2). |
| F. Sustainability requirements by investor clients | F1. For example, we have some international investors in a fund. They have been very interested in ESG issues for years. Every month we are confronted with questionnaires with specific data that they want, information. So, they are very involved, they also put pressure on us to participate in ratings, etc. (AM6).<br>F2. Some of our clients have ruled out most coal investments. They are now starting to talk about oil and gas. There are already some clients who are ruling that out as well (AM10). |

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| 4. Inadequate classification requirements for investment products | |
| G. Perception that article 9 would allow investments in transition | G1. Basically, as I understand it, they [Articles 8 & 9] would already allow investments in transition products, because the category also exists in the taxonomy. And if they say, we're going to make taxonomy-compliant investments, then I'm the taxonomy first, and then I can reflect that quite well in the fund strategy (AM6).<br>G2. We always find that at least a large proportion of investors want to operate on the basis of article nine of the SFDA. And there the CO2 driven process and also taxonomy-controlled processes are feasible (AM5). |
| H. Today's classification requirements don't fit transition | H1. And especially if you look at the area of infrastructure, where you can make a sustainable contribution to the energy transition, to the transition, etc., with bridging technologies, then it is the case that these large pots of money are so restricted by the regulatory framework that the private institutional investor's money can only be used there with great difficulty (AM11).<br>H2. And yes, that's the set of criteria that we currently have in place for our ESG investments. And yes, I mean, of course, that can be changed at any time. Yes, for certain things they can only be changed if they are also changed by the two labels, because they are both labels that we always want to have on our funds (AM2). |

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| **Overarching Dimension: Contextual risks** | |
| 5. Environmental risks | |
| I. Concern about own organization's ESG goals | I1. With LNG, I think it's probably more a question of how you view fracked gas, methane emissions. And I think that's one of those questions where each institution has to sort of decide for itself (AM7).<br>I2. CO2 emissions are also very high for natural gas (AM1). |
| J. Concern that LNG might hinder the energy transition | J1. (...) to invest in gas-fired power plants that cannot be converted to hydrogen, for example, at a later date (F1).<br>J2. And I think at the moment you can see that Germany or Europe is not as advanced as we might have thought in terms of being able to generate electricity from renewables (F3). |
| 6. Reputational risks | |
| K. Pressure from NGOs | K1. LNG is of course very critical, and even before it started in Ukraine, all the NGOs in Germany certainly warned all the big institutional investors, including us, and said you don't want to finance Brunsbüttel (AM8). |

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| | K2. Of course, anything called for by NGOs carries a certain risk, even to the extent of sabotage. Unfortunately. A great radicalisation is therefore definitely to be seen (F3). |
| L. Pressure from other stakeholders | L1. I can give you an example where we said no, we're not doing that. It was an investment in pipeline infrastructure in North America and it was in the press. This pipeline went through Indian reservations in the US. So, it was inevitable that it was going to cause problems in the long run (...). That's why, for example, we didn't put anything like that on the books or decided against it (AM9). |
| | L2. (...) or the question of "which stakeholders are affected? Especially with infrastructure, this is a very relevant question because infrastructure is always in the middle of a community or a city. That means you can't just put it there, like your LNG terminal (AM9). |

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| **Overarching Dimension: Financial Decision** | |
| 7. No investments | |
| M. Fossil fuel exclusion | M1. But where we are not investing, or where we are being very cautious, is in companies that are simply benefiting in the short term from higher oil and gas prices, because this is doubtless very temporary in nature (AM3).<br>M2. We do not invest in oil, coal, or gas. We don't invest in nuclear power because we believe it violates the "do no significant harm" criterion (AM1). |
| N. Long-term profitability concerns with bridge technology | N1. The state must create a stable framework to ensure that investments are profitable in the long term. That is also the point, because the state has a hard time finding investors. Unlike in the US, for example, where these LNG terminals have a much longer-term perspective (...) (AM10).<br>N2. So, in the US, of course, this is a bigger focus than here in Europe. That is, the transactions there are much more frequent and different than here (AM11). |
| 6. Few investments with limited participation | |
| O. No focus of investment strategy | O1. And again, when I break this [LNG] down to the portfolio, it's a very small part (AM11). |

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| | O2. Well, yes, and we are investing in that. But it's not a big focus now, so to say that bridge technology must or should have a certain share of the portfolio, that's part of the overall transition consideration (AM3). |
| P. No active investment decision, but investments via fund | P1. We invest in infrastructure mainly through funds (AM4).<br><br>P2. I mean, one of our funds is involved in the LNG terminals in Wilhelmshaven, Brunsbüttel, sort of in northern Germany. But that's not an active decision on our part, that's an investment, if you like, in a generalist infrastructure fund (AM9). |
| **Overarching Dimension: Hydrogen market regulation** | |
| 9. Production guarantee for hydrogen | |
| Q. Provide security that LNG is really a bridge technology | Q1. And without an open exit strategy, I think the risk of the pure business case for the bridge technology is much higher. And especially because, in our case, this sustainability issue has gained so much momentum with investors (AM11).<br>Q2. (...) a bridge always has an end, of course, but it can also be very long. Yes, so short bridge, long bridge. And especially when it comes to natural gas, (...). It's always a question of how long you want the bridge to be (F3). |

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| R. Ensure supply and demand | R1. We would now simply say that the product is valid for us if we can find a buyer who will take the risk for a price and also for a liability (AM5).<br>R2. Long-term off-take must be guaranteed so that the investments are made (AM10). |
| 10. Developing the market for hydrogen | |
| S. Create parallel commercial conditions for players in both LNG and hydrogen market | S1. If this is done privately for hydrogen, it must be regulated by the state (F2).<br><br>S2. And I think that this regulated regime should also be applied to hydrogen networks. That's where the state comes in because the state has to maintain the regulatory conditions. So, the state sets the regulatory conditions by law. The Federal Network Agency implements them (F2). |
| T. Signal responsibilities for regulation and market coordination mechanisms early | T1. This is also the reason why we believe it is advantageous to target European institutional investors by structuring energy system transition projects accordingly, as this will ultimately make the energy system transition more favourable for the customer (AM7).<br>T2. And I don't think that's possible without a government guarantee or a government subsidy, because from an economic point of view, we probably wouldn't have built these LNG terminals (AM3). |

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| **Overarching Dimension: Financial market regulation** | |
| 11. Transition label | |
| U. Homogenize and clarify classification requirements | U1. If the market continues to see article nine as the highest quality category and then these projects in particular cannot achieve that at all, then I think something is wrong (AM6).<br>U2. So just because you're a UNPRI signatory doesn't mean you're only doing sustainable things, but everyone interprets that as they see fit (AM9). |
| V. Set up and improve transitional finance | V1. This transitional financing is therefore extremely important (AM8).<br><br>V2. The purpose of this act of delegation is so that the projects can be financed within the framework conditions we have today. And not the way we would like the world to be in 50 years' time, the optimum. If we start with that, we won't get to the optimum. That's not the way to do it. So, parallelism and additionality are very important issues for us (AM5). |

| **Overarching Dimension: Bridge technology coordination** | |
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| 12. Active & science-based communication | |
| W. Communication based on facts and science | W1. I would very much like to get away from idealism and work on the basis of facts. I see a lot of well-intentioned idealism in politics, especially in the field of energy, but not only in the field of energy, which is often not quite targeted (AM4).<br>W2. I mean, there are ambitious targets as far as hydrogen is concerned. Everyone has to make up their own mind about how realistic these targets are or are not. I think they are very, very ambitious (F2). |
| X. Improve coordination with implementers | X1. So, I think a glaring example is the very rapid phasing out of nuclear power in Central Europe, such an issue, or where, for example, they continue to expand nuclear power around the world. Good or bad, let's leave that aside. But then a very premature and very quick exit, without really being able to form effective alternatives, even bridge technologies (AM4).<br>X2. And, of course, what has also delayed the whole process is that the German government has for a long time failed to make a clear commitment that natural gas is still needed as a bridging technology (F1). |

| 13. Improve knowledge for and about transition | |
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| Y. Improve education and legitimization of bridge | Y1. And I think that's still missing, or I think if we look at the energy issue, most people, when I walk down the street here in Zurich and I ask, where does the energy come from that you get from the socket? They don't even ask that question. It's a commodity. That's the way it's seen. The complexity behind it is not clear, and therefore the problems that come with the goal of decarbonisation and what it entails are not seen (AM4).<br>Y2. Of course, we see that the demand for energy is going to continue to grow, don't we? And in order to be able to manage that effectively in terms of the sustainability debate that we have set ourselves, but also in terms of energy security, we need to find ways of producing energy in an environmentally friendly way and distributing it efficiently, and until the technologies are mature enough to manage that optimally, we need bridging solutions (AM4). |
| Z. Balance faster time-horizons of transition with slow research and long-term investment horizons | Z1. So, we now assume that renewable energy, for example in Germany, or where it has been very strongly desired and implemented politically, without effective use of bridging technology, has led to one of the most expensive electricity mixes in the world in a very short period of time. So that's exactly what happened, because the switch was made too quickly and that had consequences, or you created dependencies and you had very high energy prices (AM4). |