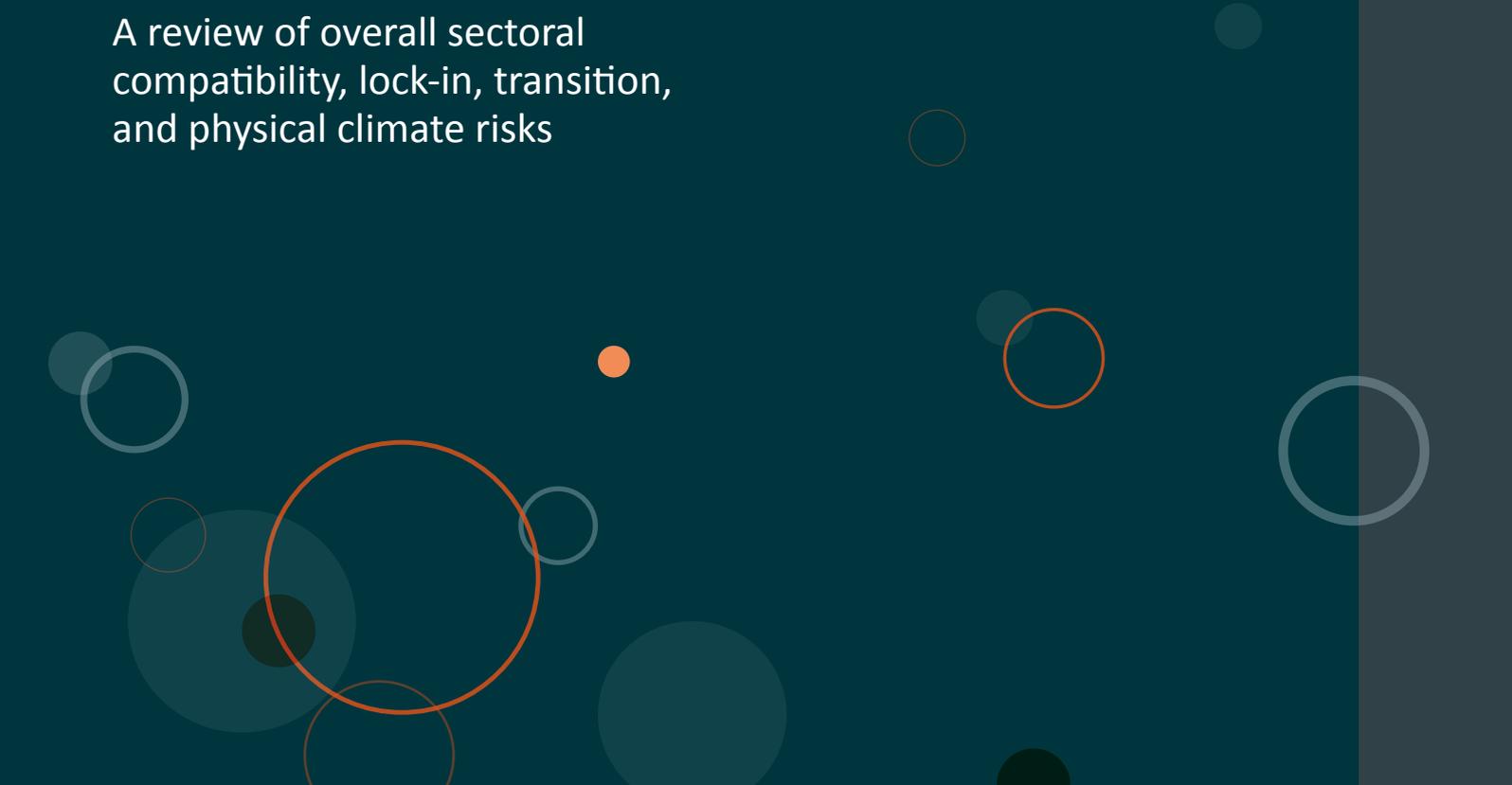


October 2021

PARIS ALIGNMENT OF GAS?

A review of overall sectoral
compatibility, lock-in, transition,
and physical climate risks



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Authors

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Disclaimer

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SUMMARY

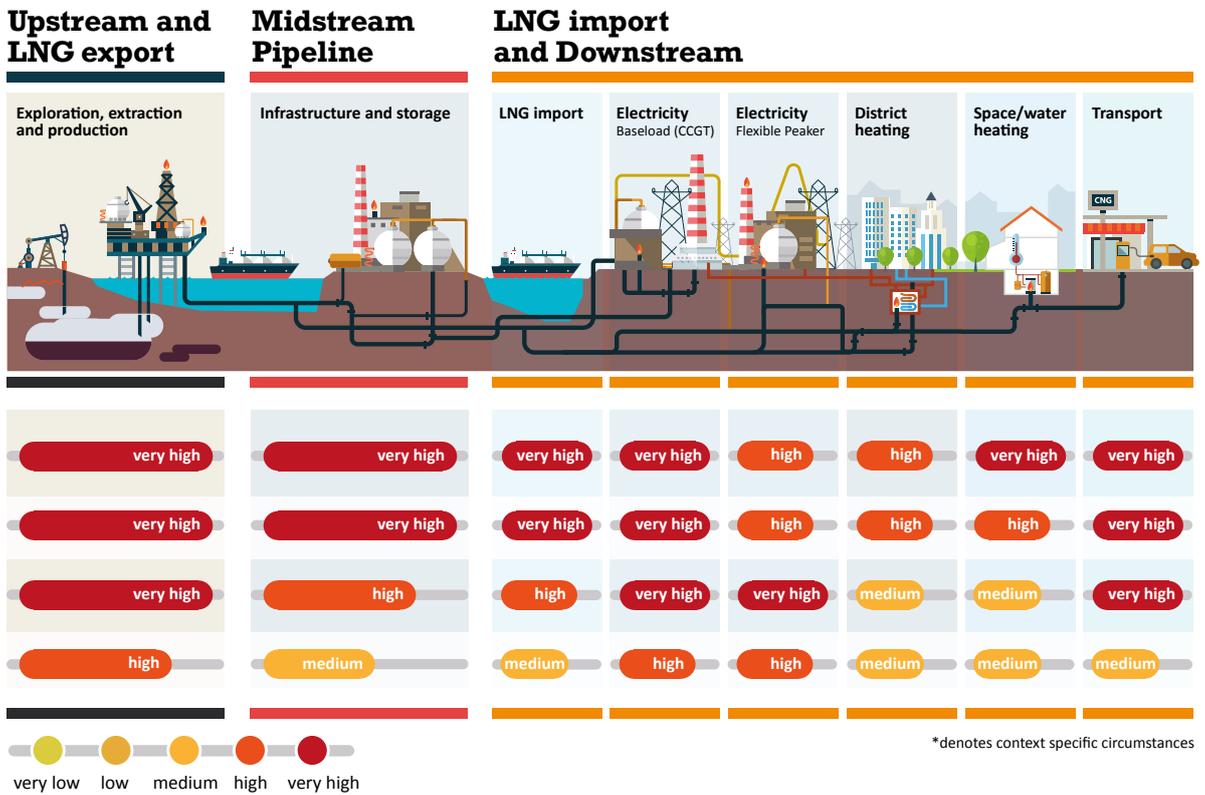
Rapid and far-reaching decarbonisation of the energy system is essential to achieving the objectives of the Paris Agreement. Of particular importance is the “critical decade” between 2020 and 2030, where emissions need to fall 7.6% every year. Committed emissions from planned and operational energy infrastructure already exceed the remaining carbon budget for a pathway consistent with a 50-66% probability of meeting the 1.5 degrees Celsius (°C) temperature goal.

In 2018, development finance institutions (DFIs) – both multilateral development banks (MDBs) and members of the International Development Finance Club (IDFC) – pledged to align their activities with the goals of the Paris Agreement. A growing number of private sector asset owners and asset managers have also begun to set net-zero targets or make other kinds of climate and environmental, social, and governance (ESG) commitments. In line with these commitments, both DFIs and the private sector have broadly moved away from directly financing coal, but they continue to provide significant finance for new gas projects and related infrastructure.

A limited number of DFIs have started to adopt restrictions for gas finance, but most DFIs lack clear and effective strategies on phasing out fossil fuel support – including gas – in line with the Paris Agreement. DFI energy and climate policy updates provide an opportunity to shift DFIs’ current lending trends to keep up with accelerated global climate targets.

Considering its significant climate impact, gas should not be seen as a bridge or transition fuel. Lifecycle assessments of gas generally undermine rationales for the use of gas as a climate-friendly alternative. Swift technological progress and the falling costs of renewable energy-based alternatives, energy storage, and the electrification of end uses means that investments in gas are not only increasingly incompatible with overall climate targets – they are also associated with serious high-emission lock-in, transition, and physical climate risks. These developments, however, have different consequences for each part of the gas value chain, from upstream extraction, export, and midstream to the various end uses.





- Upstream and export gas projects are clearly not aligned with the Paris agreement.** This includes gas exploration, extraction and production, gathering, and processing, as well as liquefied natural gas (LNG) liquefaction terminals and LNG carriers. The emissions of existing and approved oil and gas extraction projects already exceed the carbon budget consistent with 1.5°C of warming. Continued upstream gas investment undermines global climate goals, is inconsistent with the objective of reducing carbon dioxide (CO₂) emissions to net-zero by 2050, hinders exporting countries' economic diversification, and increases debt for assets at a high risk of stranding.

- Midstream pipelines face high lock-in and transition risks and cannot be considered aligned with the Paris agreement.** Despite claims that repurposing pipelines in the future provides a justification for their construction, there are a number of significant feasibility and cost challenges to repurposing gas pipelines for other uses such as hydrogen transport. There is a great deal of uncertainty regarding the feasibility and cost implications of converting gas infrastructure to transport low-carbon gases. In addition, centres of supply and demand for low-carbon gases do not correspond with current patterns in gas trade. These factors make pipelines highly likely to lock in further emissions and increases transition risk.

- **Mature and cost-competitive clean alternatives eliminate the necessity for gas for multiple downstream uses.** Lock-in and transition risks, especially in the power sector, are particularly high. Gas power plants used for baseload, generally combined cycle gas turbines (CCGT) lock-in continued emissions, as they displace and discourage additional renewables in the electricity system. Furthermore, battery technology, other storage options, smart grids, demand response, and other load management options are greatly decreasing the need for peaking power plants. An investment in gas-fired peaking power plants can only be considered Paris-aligned under exceptional circumstances where no viable clean alternatives exist and it can be shown that the plant enables and promotes greater integration of renewables. For heat, gas investments must also be avoided wherever possible. Support for gas-fired combined heat and power (CHP) should only be given in conjunction with a rapid expansion of renewable heat sources and energy efficiency improvements, in the context of a transition to lower-temperature, flexible fourth generation district heating system.
- **In new residential and commercial buildings and renovation projects, commercially available mature options for electrification eliminate the need for gas for space and water heating, as well as cooking.** Liquefied petroleum gas (LPG) for clean(er) cooking should only be considered in cases where stable electricity is not available or a feasible option. Renewable biogas produced with sustainable feedstocks should be prioritised over an expansion of fossil fuels.
- **Electrification options for road transport eliminate arguments for compressed natural gas (CNG), which offers little to no climate benefit compared to conventional fuels.**
- **LNG is similarly not Paris-aligned as a fuel for shipping.** Although mature zero-carbon alternatives are not yet commercially available for long distance shipping on a large scale, the engine and fuel storage needs for LNG present serious lock-in and transition risks. Dual-fuel engines that run on for example, marine gas oil and can later be converted to use ammonia are a superior alternative.

Renewed political momentum for climate action and increased scrutiny of lending policies and investment flows have led to growing pressure on public and private finance institutions to progress in their efforts for Paris alignment. Building on and providing input for banks' decision-making processes can facilitate Paris-aligned reforms of energy lending policies and climate strategies and action plans. DFIs can play an important role in the shift towards decarbonisation, but their strategies and current practices should be critically reviewed and reformed. To this end, DFIs should establish new investment criteria that are reflective of the climate-related and economic risks associated with gas investments, ensuring that any investment in gas infrastructure that can be avoided is avoided. For DFIs, it is important in this context to consider the rapidly evolving technological maturity and competitiveness of renewable energy-based alternatives, as well as the electrification of end uses. The objectives of DFIs' energy policies should be to mobilise finance to mainstream these alternatives universally, facilitate a just and inclusive transition, and exploit key opportunities in alternative fuel supply chains such as green hydrogen.

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ABBREVIATIONS

°C	Degrees Celsius	IPCC	Intergovernmental Panel on Climate Change
°F	Degrees Fahrenheit	IRENA	International Renewable Energy Agency
ADB	Asian Development Bank	IsDB	Islamic Development Bank
AfDB	African Development Bank	Km	Kilometre
AIIB	Asian Infrastructure Investment Bank	LCOE	Levelised Cost of Electricity
B2DS	Beyond 2°C Scenario	LDC	Least Developed Country
BAT	Best Available Technology	Li-ion	Lithium-Ion
BNEF	Bloomberg New Energy Finance	LNG	Liquefied Natural Gas
CCGT	Combined Cycle Gas Turbine	LPG	Liquefied Petrol Gas
CCS	Carbon Capture and Storage	LTS	Long-Term Strategy
CHP	Combined Heat and Power	m³	Cubic Metre
CNG	Compressed Natural Gas	MDB	Multilateral Development Bank
COVID-19	Coronavirus Disease 2019	MGO	Marine Gas Oil
CSP	Concentrating Solar Power	MMBtu	Million British Thermal Units
DFC	United States International Development Finance Corporation	Mt	Million Tonnes
DFI	Development Finance Institution	MTF	Multi-Tier Framework
DH	District Heating	MTPA	Million Tonnes per Annum
e-fuel	Electrofuel	MW	Megawatt
E3F	Export Finance for Future	NDC	Nationally Determined Contribution
EFTA	European Free Trade Association	NDB	New Development Bank
EIB	European Investment Bank	NPV	Net Present Value
ESMAP	Energy Sector Management Assistance Program	OCGT	Open Cycle Gas Turbine
ETS	Emissions Trading System	OECD	Organisation for Economic Co-operation and Development
EU	European Union	PV	Photovoltaics
EU-EE	EU Energy Efficiency Scenario	R&D	Research and Development
FDI	Foreign Direct Investment	RISE	Regulatory Indicators for Sustainable Energy
gCO₂e	Grammes of CO ₂ Equivalent	SDG	Sustainable Development Goal
GHG	Greenhouse Gas	SIDS	Small Island Developing States
Gt	Gigatonne	TAPI	Turkmenistan-Afghanistan-Pakistan-India
GWP	Global Warming Potential	TEG	Technical Expert Group
IDB	Inter-American Development Bank	UNFCCC	United Nations Framework Convention on Climate Change
IBRD	International Bank for Reconstruction and Development	USD	United States Dollar
IDA	International Development Association	WACC	Weighted Average Cost of Capital
IDFC	International Development Finance Club	WBG	World Bank Group
IEA	International Energy Agency	WHO	World Health Organisation
		WRI	World Resources Institute

1. INTRODUCTION

Rapid and far-reaching decarbonisation of the energy system is essential to achieving the objectives of the Paris Agreement. Of particular importance is the “critical decade” between 2020 and 2030, where emissions need to fall 7.6% every year (UNEP, 2019). The misconception persists that gas can play a significant “bridge” role in decarbonisation. Committed emissions from planned and operational energy infrastructure already exceed the remaining carbon budget for a pathway consistent with a 50-66% probability of meeting the 1.5 degrees Celsius (°C) temperature goal (Tong *et al.*, 2019).

The most promising and cost-efficient strategy to decarbonise the energy system is to electrify all possible end uses and shift electricity generation away from fossil fuels and towards renewable energy. The technological maturity of wind and solar power and electricity storage options has progressed rapidly, as have electric alternatives for many end uses. Shifting electricity generation away from fossil fuels is not only a climate change imperative but also represents the only approach that avoids exposing developing countries to significant transition and lock-in risks. The decarbonisation of developing countries’ energy systems can also help strengthen their adaptive capacity and improve resilience, given the vulnerability of the gas value chain to physical climate risks. This is essential, as developing countries are simultaneously the least responsible for climate change and the most vulnerable to its impact. They have the great challenge of expanding energy access and meeting growing energy demand, while having the least resources to finance decarbonisation.

In 2017, multilateral development banks (MDBs) and International Development Finance Club (IDFC) members pledged to align their financial flows with the objectives of the Paris Agreement, which implies that banks must redirect their activities to make their finance flows “**consistent with a pathway towards low greenhouse gas emissions and climate-resilient development**” as per Article 2.1c of the Paris Agreement (UNFCCC, 2015). As such, for development finance institution (DFI) support to be Paris-aligned, it must be consistent with the Paris temperature goal. Specifically, this requires DFIs to ensure that operations are consistent with the objective of keeping global warming well below 2°C, with the aim to limit the global temperature rise to a 1.5°C increase, while also minimising temperature overshoot and negative emissions and enhancing resilience and adaptive capacity. Considering that developing countries are the most vulnerable to and are already suffering from the impacts of climate change, it is central to DFIs’ mandate to support developing countries to avoid a high emission development pathway. Therefore, DFIs must ensure that they not only do no harm (which they would do if they were to undermine the transition), but also take a lead in supporting and accelerating the low-carbon transition (I4CE, 2019).

DFIs, notably MDBs and IDFC members, are in the process of developing tools and approaches to align themselves with the Paris Agreement. This paper seeks to explore the gas debate in the context of DFIs’ alignment efforts. We begin by outlining our methodology, before reviewing the current status of DFIs’ investments in gas infrastructure, considering the climate impact of gas and different modelled Paris-aligned pathways. We then discuss various investment considerations with regard to the gas value chain, based on inputs from Paris-compatible scenarios (sectoral criteria), lock-in risks, transition risks, and resilience considerations. We then discuss the results of our analysis, draw conclusions, reflect on the study’s limitations, and recommend areas for further research.



1.1 METHODOLOGY

In order to provide guidance on an approach to determining Paris alignment of gas-related investments, we draw on previous work on the Paris alignment of natural gas, recent publications on climate modelling, a review of the current status of technological progress in terms of alternatives, and recent updates to development banks' Paris alignment approaches.

An initial approach was proposed in Germanwatch and NewClimate's 2018 working paper "Aligning Investments with the Paris Agreement Temperature Goal - Challenges and Opportunities for Multilateral Development Banks" (Germanwatch & NewClimate Institute, 2018). The working paper classifies gas-related investments in electricity generation as "conditionally aligned" if:

- the project is economically viable despite factoring in a robust shadow carbon price;
- the project will be decommissioned before a targeted year for full decarbonisation;
- the project is aligned with national decarbonisation pathways; and
- based on additional factors such as future demand, system flexibility, idle capacity, capacity pipeline, and infrastructure repurposing.

Similarly, pipelines in the 2018 working paper could be considered conditionally aligned if: there is sufficient future demand; if current infrastructure capacity is insufficient for this level of future demand; and if the projects is consistent with a national 2050 decarbonisation pathway.

Since then, the technological progress of various alternatives has further reduced the need for gas-fired energy generation, a number of DFIs have presented their approaches towards Paris alignment, including guidance on gas, and new political momentum has pushed the debate to the forefront of development finance discussions. Furthermore, the scientific understanding of carbon budget constraints and the significant greenhouse gas (GHG) impact of gas, including the amount of fugitive emissions, has also notably improved (see Section 2.2). We therefore revisit our previous proposed investment guidance for gas for different parts of the value chain, integrating current climate science, including new findings regarding climate change impacts and risks, as well as an updated appraisal of the technological maturity and costs of alternatives.

1.2 JOINT ALIGNMENT APPROACH

In their effort to align themselves with the Paris Agreement, DFIs have established a number of dimensions that lay out their approach to alignment. In 2018, MDBs proposed a joint framework, based on six "building blocks", which sets out their approach to meeting the goals of the Paris Agreement (World Bank, 2018). Also in 2018, IDFC members proposed a similar parallel framework with a number of common elements.



Table 1: MDB and IDFC Paris Alignment approaches, based on IDFC (2018) and World Bank (2018)

MDB Paris Alignment “building blocks”	IDFC alignment commitment and actions
1. Alignment with mitigation goals: operations compatible with the mitigation objectives of the Paris Agreement.	1. Increasingly mobilise finance for climate action.
2. Adaptation and climate resilience: operations ensuring climate-resilient development and the promotion of adaptive capacity.	2. Support country-led climate-related policies.
3. Provision of scaled climate finance: mobilisation of finance and direct lending to support an accelerated transition.	3. Catalyse investments and mobilise private capital.
4. Engagement and policy development support: technical assistance and collaborative partnership building.	4. Recognise the importance of adaptation and resilience, especially in the most vulnerable countries.
5. Reporting: development and harmonisation of reporting approaches.	5. Support the transition from fossil fuels to renewable energy financing.
6. Alignment of internal activities: alignment of MDBs’ internal processes and operations/policies.	6. Internal transformation of institutions (IDFC members).

Although still under development, preliminary assessment criteria for the first two MDB building blocks have been drafted, which are intended to be applied to project types that are not included in the MDBs’ universal positive or negative lists (Rydge, 2020). Our analysis of the Paris alignment of gas investments focuses on the first and second building block of the joint MDB Paris alignment approach, but also discusses connections with other relevant building blocks of the approach, where appropriate. In the mitigation building block, the framework recommends evaluating a project’s (in) consistency with respect to countries’ national plans and nationally determined contributions (NDCs)/long-term strategies (LTs), sector-specific mitigation objectives, clean technology alternatives, lock-in risks, and transition risks. In the adaptation building block of the framework, MDBs intend to assess supportive activities in terms of their alignment with countries’ climate-resilient development pathways via context-specific evaluation of physical climate risks.

We provide inputs on the interpretation of evaluation criteria MDBs have defined for the first two building blocks of the joint Paris alignment framework and discuss how they relate to gas investments. We do not focus on specific countries, but, rather, provide a high-level interpretation of evaluation criteria, hence excluding the dimensions that directly refer to countries’ NDCs and LTs. However, it should be noted that current NDCs are cumulatively insufficient to reach the Paris Agreement’s temperature goals (UNEP, 2019, 2020a), many are out of date, having been submitted in 2014 and 2015, and many developing countries have not yet developed an LTS.

For most value chain components analysed in this report, elements of the MDB alignment approach can inform more restrictive policy development. For those value chain components where DFI support is not categorically non-aligned, we propose a number of guiding questions that DFIs can use to evaluate the context-specific consistency of the investment requests with the Paris Agreement. Figure 1 provides an overview of the building blocks evaluated in this report, as well as an indicative overarching evaluation logic.

Figure 1: Selection of questions from MDB Paris alignment framework for mitigation and adaptation

If the **project is gas related** (full value chain):

			yes	no	unclear
Mitigation	Sector-specific criteria	Is the project consistent with sector-specific Paris Agreement criteria/carbon budgets?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Lock-in risks	Does the project promote opportunities to transition to Paris-aligned activities, i.e. no carbon lock-in risks?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Transition risks	Is the project economically viable, pricing in transition risks, i.e. low risk of stranding?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Adaptation	Resilience	Does the project account for physical climate risks?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Resilience	Does the project build adaptive capacity and resilience?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

If any response is no: **NOT ALIGNED** 

In the mitigation building block, MDBs include an evaluation of project consistency with national and sector-specific Paris alignment criteria, i.e. the compatibility of the project vis-à-vis the remaining carbon budget. Benchmarks, such as carbon budget scenarios, emission intensity thresholds, or renewable energy deployment scenarios, can also be applied to exclude clearly misaligned projects in a specific sector (Germanwatch & NewClimate Institute, 2018). We reference available modelled benchmarks for the sectors we analyse.

Furthermore, the joint Paris alignment framework also assesses a project’s potential for misaligned technology lock-in and transition risks, which can lead to stranded assets. We explore how these criteria can be applied to gas projects at different stages of the value chain and what they mean for DFI support for gas projects in most contexts.

In the adaptation building block, the joint Paris alignment framework focuses on context-specific assessment of the physical climate risks associated with a project and checks whether projects contribute to building adaptive capacity, helping countries pursue resilient development pathways. While this will vary according to the local context, we assess whether gas projects are generally more prone to physical climate risks than alternative technologies.

Based on the conclusions and the relevant lock-in, transition, and physical climate risks, we propose potential investment guidance for different kinds of direct investments in the gas value chain.

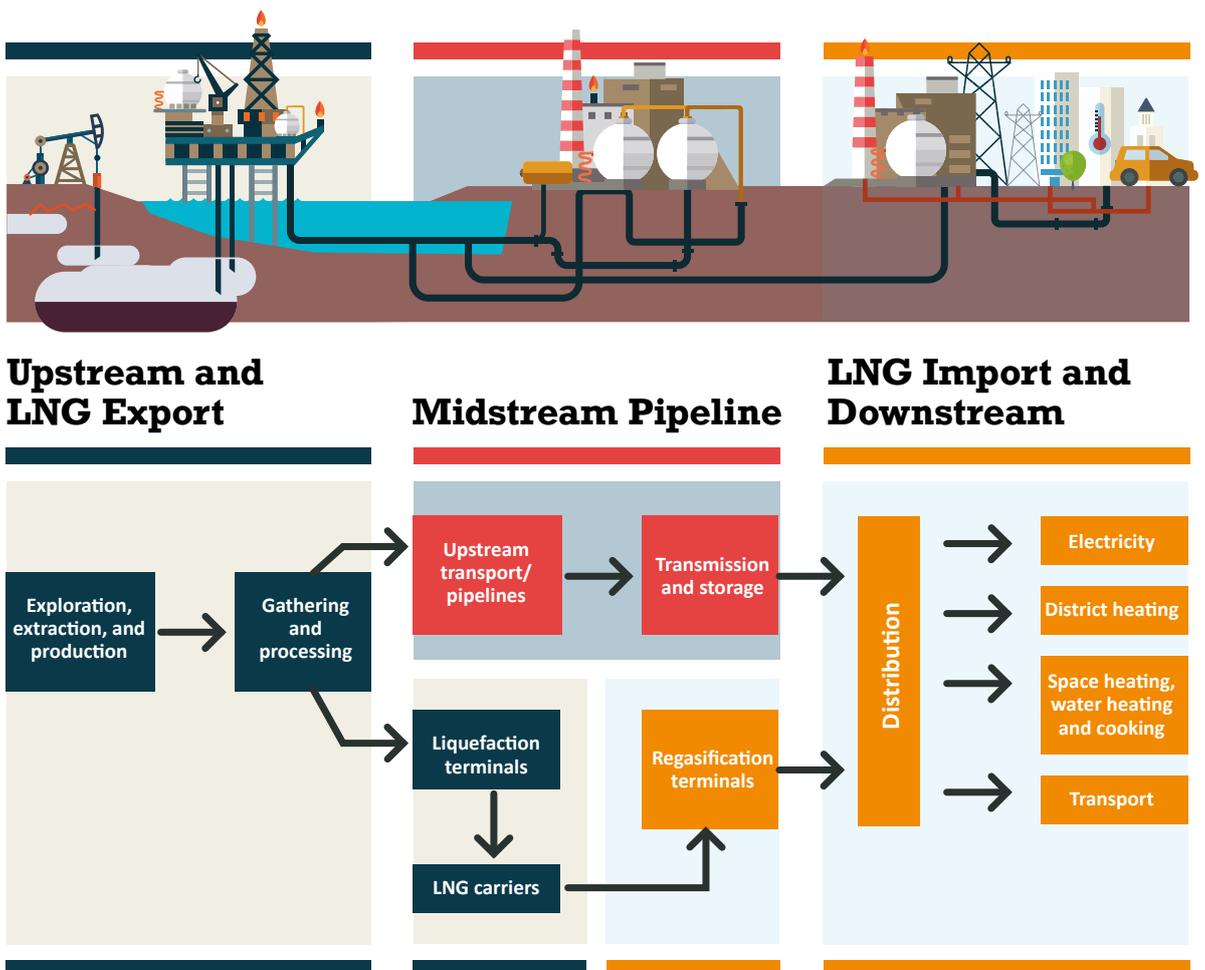


1.3 DEFINITION OF VALUE CHAIN COMPONENTS

Our analysis covers a number of elements up and down the gas value chain. Based on the investment considerations, we propose the following three asset groupings: (1) upstream and liquefied natural gas (LNG) exports; (2) midstream pipelines; and (3) LNG imports and downstream—the last of which includes different sub-categories based on

end use. Although usually understood as a midstream value chain element, we consider LNG export and import infrastructure separately and in conjunction with the upstream and downstream parts of the value chain, respectively, given their similarities in terms of the associated lock-in and transition risks. Furthermore, we consider the climate-related aspects of new infrastructure (greenfield), refurbishment (brownfield), and retirement and decommissioning.

Figure 2: Gas value chain components



2. BACKGROUND AND CURRENT STATUS

As a growing number of countries – both developed and developing – set net-zero targets, more attention is also being paid to the financial support to emissions-intensive investments made abroad. In particular, there is a growing political debate about support for fossil fuels in development finance. While some frame gas as a transition or “bridge” fuel, the adverse climate impacts of gas, its lock-in and transition risks, and the technological maturity and competitiveness of alternatives significantly limit the extent to which gas can and should still play a role in development efforts.

The European Union (EU) has already announced that it “will discourage all further investments in fossil fuel based energy infrastructure projects in third countries¹, unless they are fully consistent with an ambitious, clearly defined pathway towards climate neutrality in line with the long-term objectives of the Paris Agreement and best available science” (Council of the European Union, 2021). As part of the international coalition Export Finance for Future (E3F), a group of EU countries consisting of Denmark, France, Germany, the Netherlands, Spain, and Sweden along with the United Kingdom (UK), have committed to eliminating public export guarantees for coal and phase out support for fossil fuel projects, although agreed principles are yet to be laid out in detail in the majority of the countries (Government of France, 2021). The UK enacted a new policy on national government support for the fossil fuel energy sector overseas in March 2021. Under the policy, the UK will stop export finance, aid funding, and trade promotion for fossil fuel sectors, including gas, albeit with several exceptions (BEIS, 2021). Additionally, the new Biden-Harris administration in the United States (U.S.) has directed the federal government to “seek to end international investments in and support for carbon-intensive fossil fuel-

based energy projects”; “work with other countries, through both bilateral and multilateral engagements, to promote the flow of capital toward climate-aligned investments and away from high-carbon investments”; and for the U.S. International Development Finance Corporation (DFC) to “implement a net-zero emissions strategy to transition its portfolio to net-zero emissions by 2040” (The White House, 2021). In its new guidance on fossil fuel energy at the MDBs, the US, however, allows for narrow support for gas (US Treasury, 2021). This is particularly significant, considering that the U.S. is often one of the largest shareholders in MDBs.

These national policy trends are significant not only for bilateral development finance, but also because these countries are major shareholders in MDBs and will have considerable influence on their ongoing financing of fossil fuels on both an individual and collective basis.

2.1 DFIS’ ENERGY INVESTMENT POLICIES

Between 2017 and 2019, public financial support for fossil fuels was over twice as high as that for renewable energy infrastructure (Muttitt *et al.*, 2021). In 2020, total investments in oil and gas infrastructure by the World Bank Group (WBG), Inter-American Development Bank (IDB), Asian Development Bank (ADB), Asian Infrastructure Investment Bank (AIIB), African Development Bank (AfDB), European Investment Bank (EIB), European Bank for Reconstruction and Development (EBRD), Islamic Development Bank (IsDB), and New Development Bank (NDB) amounted to about United States Dollar (USD) 3.4 billion (see Table 2).

¹ For the EU, third countries are any countries that are not EU or European Free Trade Association (EFTA) member states.

Table 2: DFI's energy sector investments (million USD) in 2020, based on Oil Change International (2021)

Sector	ADB	AfDB	AiIB	EBRD	EIB	IDB	IsDB	NDB	WBG
Renewable energy* and batteries	\$ 673	\$ 13	\$ 95	\$ 671	\$ 3,670	\$ 988	\$ -	\$ -	\$ 1,169
Oil and gas	\$ 233	\$ 3	\$ -	\$ 984	\$ 923	\$ 273	\$ 21	\$ -	\$ 955

* Excluding hydro and biomass/biofuels

DFIs' current energy lending approaches vary in both breadth and depth with regard to fossil fuel financing and specifically gas financing. Although no DFI has a complete categorical exclusion of gas, there is a wide spectrum of DFI policies concerning gas, from restrictive policies against gas finance with some exceptions to DFIs acting as significant financiers of gas and related infrastructure. DFI support for gas-related projects takes various forms, including lending for new development, refurbishment, retirement and decommissioning, guarantees, and technical assistance and advisory services.

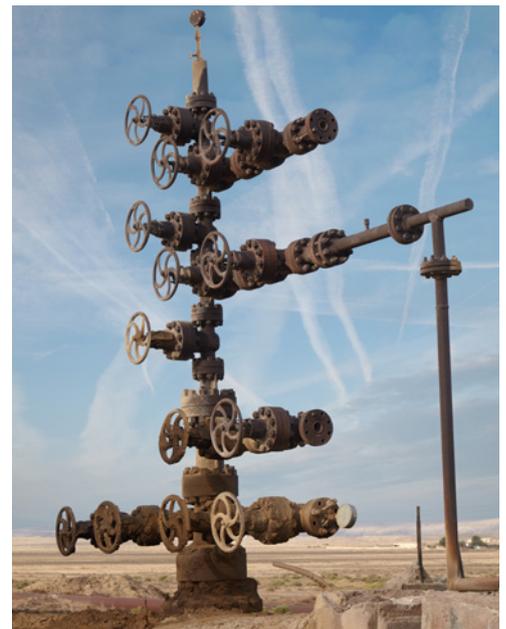
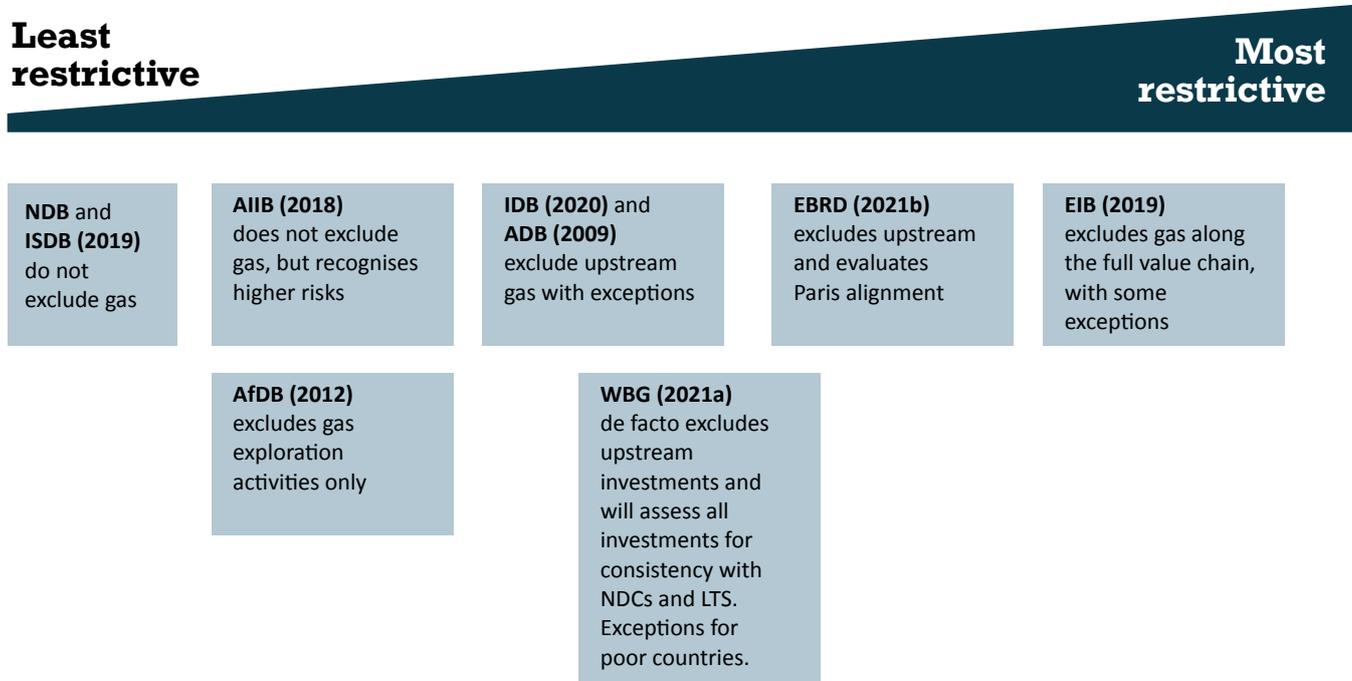


Figure 3: Restrictiveness in MDBs' gas policies



The EIB has comparatively the most restrictive policy with regard to (direct) investments in gas-related infrastructure. The EIB's energy lending policy excludes most kinds of investments in unabated fossil fuels along the entire value chain from 2022 onwards (EIB, 2019). As such, the EIB is the only DFI that excludes support to downstream gas projects, albeit with some notable exceptions, including support for LNG-fuelled vessels in the maritime sector (see Figure 3).

The WBG (2021a), IDB (2020), ADB (2009), and EBRD (2021b) all exclude support for upstream gas projects in their draft methodologies, although some with notable exceptions. The AfDB (2012) excludes gas exploration only. The NDB (no dedicated energy policy), the ISDB (2019), and the AIIB (2018) do not formally exclude support to gas projects, irrespective of the stage of the value chain.

Generally, with the exception of the EIB, many DFIs imply that they see gas as playing a role in the decarbonisation of energy systems, and some DFIs explicitly or implicitly support coal-to-gas switching. Although an investment in fossil fuels, this is

even controversially categorised as climate finance in the joint MDB IDFC definitions of climate mitigation finance (MDBs, 2020). The EBRD previously described the switch to gas as "a key step towards a cleaner energy system for many countries" (EBRD, 2019, pp. 37), but recently pledged to only support gas projects that credibly align with a low-carbon strategy (EBRD, 2021a). The ADB refers to the switch from coal to cleaner alternatives, including gas, as desirable in its energy lending policy (ADB, 2009), although a new draft energy policy proposes a number of conditions that may lead to some restrictions on gas lending (ADB, 2021). The AIIB presents investment support to gas-fired power generation as a part of a country's transition towards a sustainable, low-carbon energy mix (AIIB, 2018, pp. 17). The WBG Climate Change Action Plan 2021-2025 cites the World Bank's existing policy of not financing upstream oil and gas upstream projects since 2019 and mentions a planned assessment for consistency with NDCs, LTSs, and mitigation of "long-term carbon lock-in" risks, but still implies that the World Bank sees a useful role for gas in a transition away from coal (World Bank, 2021a).

2 Indirect investments through support of counterparties is a further area of consideration. The EIB is currently working to develop counterparty alignment guidelines.

2.2 GAS IN THE CONTEXT OF PARIS AGREEMENT GLOBAL WARMING LIMITS

Although a number of DFIs are currently updating their lending policies, most DFI energy lending policies are not yet consistent with Paris-compatible transition scenarios and require a significant shift to play a more proactive role in helping developing member countries decarbonise. Current policies often do not adequately reflect gas's climate impacts, overestimate both the needs and development benefit of gas, and are overly optimistic in terms of the business case for both gas infrastructure and fossil fuel-based end uses.

The Intergovernmental Panel on Climate Change (IPCC) is “highly confident” that limiting global warming to 1.5°C with no or limited overshoot depends on reaching net-zero carbon dioxide (CO₂) emissions by the middle of the 21st century and deep reductions in non-CO₂ emissions (IPCC, 2018a). To achieve the 1.5°C target, global emissions must be cut by an average 7.6% per year during the “critical decade”³ from 2020 to 2030 (UNEP, 2019). The IPCC’s 1.5°C-compatible mitigation pathways include a significant decrease in gas use in the energy system by 2030 and a rapid decline in the carbon intensity of electricity and the growing electrification of end uses up to 2050 (IPCC, 2018b).

CO₂ emissions from already developed fossil fuel reserves (oil, gas, and coal mines and fields that are currently under construction or in operation) are likely to exhaust the 2°C carbon budget and put the 1.5°C temperature goal out of reach (IEA, 2021b).

Although at the point of combustion, gas is cleaner than other fossil fuels in terms of CO₂ and other local pollutants, it is nevertheless a fossil fuel with a significant climate impact (Balcombe *et al.*, 2017). Looking beyond the point of combustion, fugitive emissions severely undermine gas’s climate benefit.

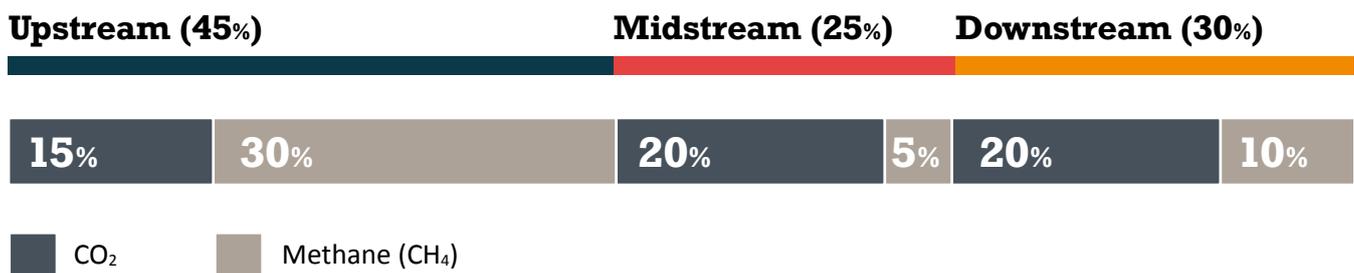
Methane, the main component of gas, is a highly potent GHG and the second largest driver of climate change. Thirty-five percent of human-caused methane emissions come from the fossil fuel sector, 23% of which results from oil and gas extraction, processing, and distribution (UNEP, 2021). Methane has a shorter atmospheric lifetime than CO₂, but a significantly higher global warming potential (GWP): 84-87 times more than CO₂ over a 20-year timeline and 28-36 times more than CO₂ over a 100-year period (IEA, 2020d).⁴

Methane emissions from gas in 2019 were estimated to be 43 million tonnes (Mt), about two thirds of which originated from upstream and midstream activities (IEA, 2020a). Key sources of methane leakage include well completions, liquid (LNG) unloading processes, pneumatic components and compressor units in transmission infrastructure, and incomplete combustion at the end use. Super-emitters, such as well blowouts or pipeline ruptures resulting from poor operation and maintenance or inefficient process equipment, also have a significant impact (Balcombe *et al.*, 2017). Historically, there have been a number of estimates of methane leakage in the upstream value chain, but recent analysis by Traber and Fell (2019) suggests that leakage rates are likely to be significantly underestimated. This is supported by a recent study in the journal *Nature*, which found that previous estimates of global anthropogenic fossil fuel methane emissions (not naturally occurring) are likely to be underestimated by 25-40% (Hmiel *et al.*, 2020).

³ Also referred to as the “decisive decade” by US President Biden in the Leaders Summit on Climate on 22 April 2021.

⁴ As GWP 100 is the most commonly used timeframe to set goals and compare warming impacts, we also use it as the primary basis for our analysis.

Figure 4: Value chain component-specific emissions, based on McKinsey & Company (2020b)



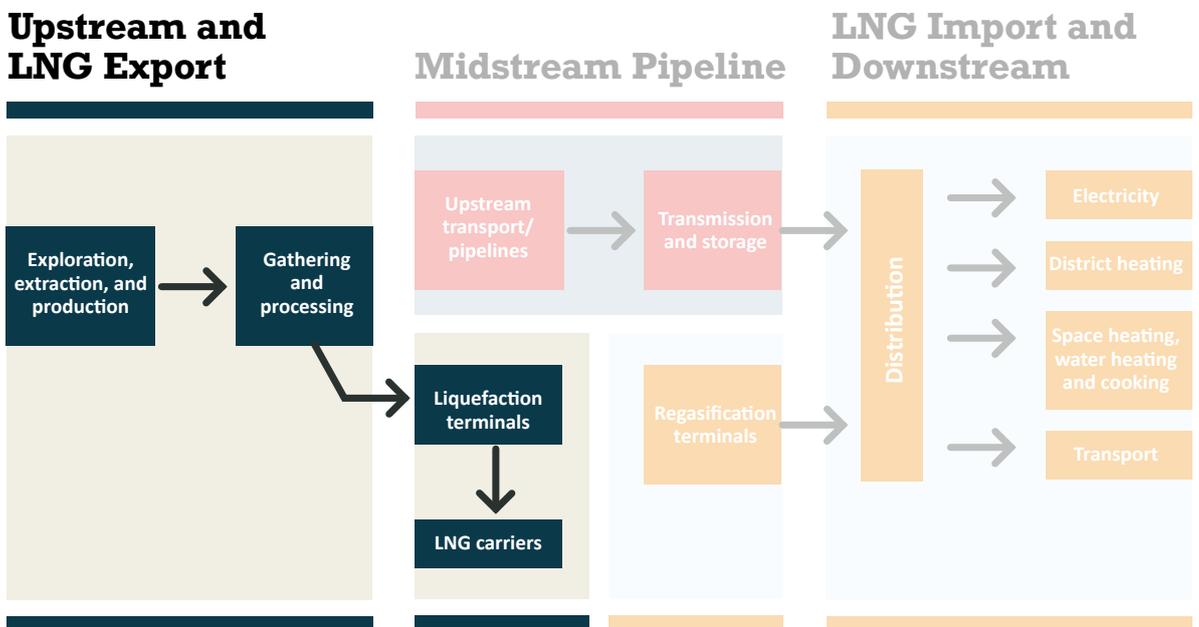
High methane leakage rates can decrease or fully offset the mitigation benefits of switching from coal to gas for electricity generation. At normal rates of upstream methane leakage (e.g. 0.9-3.6%, as measured across the U.S.), considering only the downstream CO₂ combustion emissions would result in the underestimation of climate impact by 16-65% (GWP 100) or 38-157% (GWP 20) (Burns and Grubert, 2021). Depending on the timeframe assumed in the conversion of methane’s global warming rate to a CO₂ equivalent, gas’s climate impact can be as damaging as that of coal for energy systems, with methane leakage rates of around 4% (GWP 20) or 7% (GWP 100). Remote sensing of methane leakage from some U.S. oil and gas extraction basins reveals leakage rate estimates of 1.4-3.9%, while two of the world’s largest gas fields in Turkmenistan are estimated to have a collective methane leakage rate of approximately 4.1% (Schneising et al., 2020).



3. UPSTREAM AND LNG EXPORT

Upstream and LNG export infrastructure includes exploration, extraction and production, gathering, processing, and LNG liquefaction terminals and carriers. Although export-oriented LNG projects are often seen as a separate category from upstream projects, they both face similar considerations with regard to lock-in and transition risks. Upstream and LNG export investments are misaligned in terms of a number of different factors: sector-specific criteria and comparisons with climate modelling, impacts on the fossil fuel lock-in of economies, and transition risks. These are discussed in further detail below, along with resilience considerations.

Figure 5: Upstream and export midstream natural gas value chain components





3.1 INPUTS FROM PARIS-COMPATIBLE SCENARIOS: SECTOR-SPECIFIC CRITERIA

Current gas production is already at levels well above Paris-aligned levels. Therefore, DFIs' support for upstream gas projects, including exploration, extraction, and processing, as well as export infrastructure, is inconsistent with sector-specific Paris Agreement criteria. Global gas production levels must decline by 3% per year between 2020 and 2030 to be aligned with the 1.5°C target (SEI *et al.*, 2020). If production capacity increases in line with governments' current plans,⁵ gas generation levels would increase by an average of 2% per year through 2030 (SEI *et al.*, 2020), undermining the Paris temperature targets. Support for, or investment in, upstream gas projects that increase gas production, through both the development of new capacity and lifetime extension of existing assets, is therefore inconsistent with the Paris Agreement.

DFIs' support for export infrastructure (both greenfield projects and refurbishments that extend asset lifetime), such as LNG liquefaction terminals, indirectly promotes and enables increased levels of gas extraction. DFI support for LNG export infrastructure is therefore similarly inconsistent with sector-specific Paris Agreement criteria.

3.2 LOCK-IN RISKS

DFIs' support for upstream gas projects undermines opportunities to transition to Paris-aligned activities by contributing to carbon-intensive technology lock-in.

The long lifetime of gas infrastructure and its associated significant climate impact contradict claims that it can serve as a transition fuel. The carbon lock-in potential of upstream gas investments is particularly high in that it also drives continued and expanded reliance on gas in downstream segments of the value chain—especially in the producing country (Muttitt *et al.*, 2021).

Investments in extraction, processing, and export-oriented gas infrastructure in resource-rich countries can generate foreign income; such investments are also likely to have a number of adverse impacts, namely, the so-called resource curse, including Dutch disease, where oil and gas exports undermine other sectors' export competitiveness, leading to increased dependence on fossil fuel extraction and uncertain overall economic benefits (IMF, 2014). Furthermore, expectations of plentiful domestic fossil fuel resources tend to lower efforts to increase energy efficiency and the expansion of renewable energy (Muttitt *et al.*, 2021). This represents a form of lock-in, in that a country's dependence on export revenue generated from fossil fuels is likely to undermine economic diversification and prevent the country from pursuing a broader sustainable development pathway.

⁵ Government plans and projections from Australia, Canada, China, Indonesia, Norway, Russia, and the U.S. are considered in this analysis (SEI *et al.*, 2020).

3.3 TRANSITION RISKS

In 1.5°C/well below 2°C-compatible scenarios, demand for gas steadily declines, meaning that continued investment in upstream and LNG export infrastructure is highly vulnerable to transition risks.

Some industry analysts, fossil fuel producers, and oil and gas companies still project sustained gas demand (see Table 3). These projections are used to justify continued investment in upstream gas. However, these projections disregard the energy-specific carbon budget and the Paris 1.5°C/well below 2°C temperature goal. Sector modelling of energy demand growth for the 1.5°C/well below 2°C scenario shows a peaking of gas in the energy system either immediately or in the near future (before 2025), with a subsequent decline of up to 85% by 2050 (see Table 3). Notably, in the recent International Energy Agency (IEA) Net Zero Scenario, no new oil or natural gas fields are developed beyond existing fields and those already approved for development (IEA, 2021b). The IEA further notes that many of the LNG liquefaction terminals for export currently planned or under construction will also be stranded in a net-zero transition.

Transition risks for upstream gas are therefore significant, and considering the growing number of countries committing to net-zero carbon targets, supply is increasingly likely to outstrip demand, eventually resulting in a downward pressure on gas prices and stranded assets, where gas prices fall below plants' break-even price (Cust, Manley and Cecchinato, 2017). Capacity additions, specifically in LNG infrastructure, already outpaced demand growth in multiple key markets before the coronavirus disease 2019 (COVID-19) crisis (IGU and BCG, 2019). Weaker outlooks for gas resulted in multi-billion asset write downs in 2020 (Felix and Bousso, 2020). During this period, renewables continued to expand rapidly, and the IEA now expects that the renewable installed capacity will overtake gas well before the end of 2022 (Evans, 2021).

The macroeconomic risks associated with natural gas export dependence (resource curse, see Box 1), in combination with the risk of stranded assets, leave no economic rationale for new gas extraction, generation, and export infrastructure (Muttitt *et al.*, 2021).

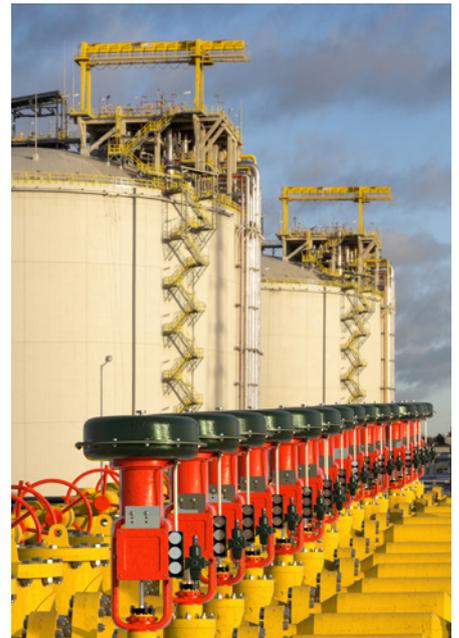


Table 3: Gas sector outlook and scenarios

	Scenario	Paris-aligned	Base year	Gas demand peak	Horizon	Role in energy system
IPCC (2018)	1.5°C low overshoot, limited negative emissions pathway (median)	✓	2020	2020	2050	-43%
	1.5°C low overshoot, limited negative emissions pathway (min)	✓	2020	2020	2050	-85%
BNEF (2020a)	NEO Climate	✓	2019	2023	2050	-76%
BP (2020)	Net Zero	✓	2018	2025	2050	-35%
IRENA (2021b)	1.5°C	✓	2021	2025	2050	-48%
IEA (2021a)	Net Zero by 2050	✓	2020	2020	2050	-55%
IEA (2020d)	Sustainable Development	⊛*	2020	2025	2040	-12%
BNEF (2020a)	NEO Economic Transition	✗	2020	-	2050	+15%
IEA (2020d)	Stated Policies	✗	2020	-	2040	+30%
BP (2020)	Business-as-usual	✗	2018	-	2050	+33%
McKinsey & Company (2021)	Demand projection	✗	2019	2037	2050	+6%
ExxonMobil (2019)	Demand projection	✗	2017	-	2040	+36%
Shell (2021)	Demand projection	✗	2020	-	2040	+41%
Gas Exporting Countries Forum (2021)	Demand projection	✗	2019	-	2050	+50%

*Assumes a smaller role for renewable expansion and large amounts of negative emissions after 2040, with questionable feasibility. The scenario would give a 66% chance of limiting warming to 1.8°C but may lead to an overshooting of 2°C (Trout, 2019).

Box 1: Just and inclusive transition

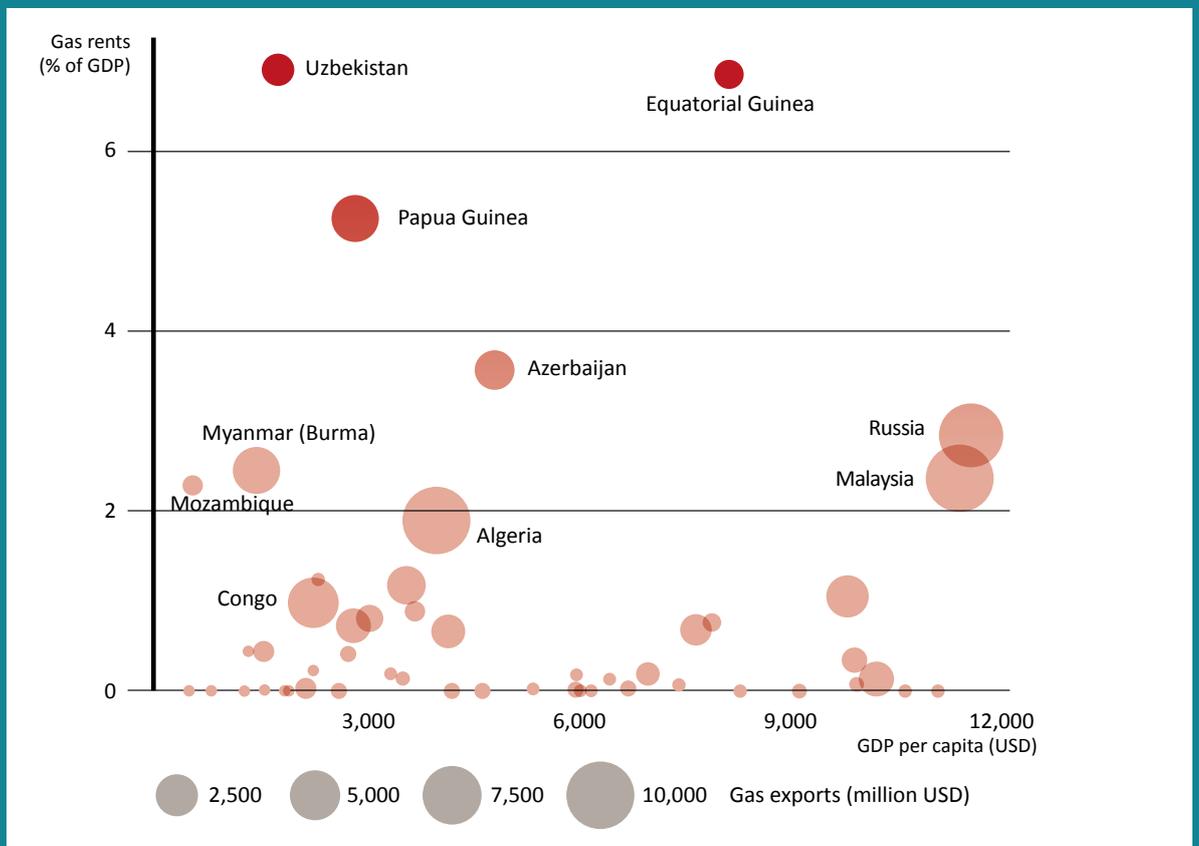
Multiple low-income countries, especially in Africa, are in the process of building natural gas export capacity, thus increasing their dependence on gas exports (see Figure 6). This expansion is misaligned with the Paris temperature goal of 1.5°C/well below 2°C, and its economic and development impacts are uncertain.

Many (developing) countries expect resource rents and improved energy security from the exploitation of their domestic gas resources. However, overall, economic returns are at the very least uncertain and could even be negative. Developing countries with fossil fuel resources often experience a “resource curse”, wherein the extraction, production, and export of fossil fuels adversely affects the country’s output and economic development. Capital-intensive natural resource projects in developing countries often drive an influx of large volumes of foreign investment, but the lack of domestic expertise means that much of this value is recycled back to foreign suppliers, technicians, and investors. In addition, the resulting appreciation of the domestic currency can negatively impact other export-oriented industries/sectors, as it renders their exports less

competitive (Dutch disease). Commodity price volatility, as well as the absence of strong institutions capable of limiting destructive rent-seeking effects, can be other factors that often contribute to the correlation between high natural resource wealth and low growth.

In these contexts, DFIs should provide support for a just transition away from all fossil fuels or the leapfrogging of fossil fuels where they are not yet developed). This would help developing countries avoid the resource curse and future stranded assets by supporting opportunities for inclusive growth (especially for those affected or most vulnerable) and investing in clean energy. DFIs should employ project indicators and assessment metrics that help prioritise funding requests targeting projects that promote just and inclusive transitions for workers and communities in affected sectors. DFIs should also review and reform their policy-based lending support to ensure that inclusiveness and justice are integral components of any fungible financial support. Last but not least, DFIs should engage to promote local, regional, and global efforts towards just and inclusive transitions in developing countries.

Figure 6: Gas exporting developing countries, based on World Bank (2021)



3.4 RESILIENCE

The physical impact of climate change already has implications for investment considerations for upstream and export-oriented midstream gas infrastructure. Current and probable future impacts should be taken into consideration to maximise, or, at the very least, not undermine, the climate resilience of assets and impacted communities.

Gas extraction and processing, especially in the case of hydraulic fracturing of shale (unconventional gas production), is extremely water-intensive (World Bank, 2016). In regions with limited water supply, upstream gas activities put additional pressure on water reserves, thereby also affecting other water-dependent sectors. Areas of high levels of water stress often coincide with shale formations (Kondash, Lauer and Vengosh, 2018). Physical climate risks such as more frequent or longer periods of drought are likely to aggravate the situation.

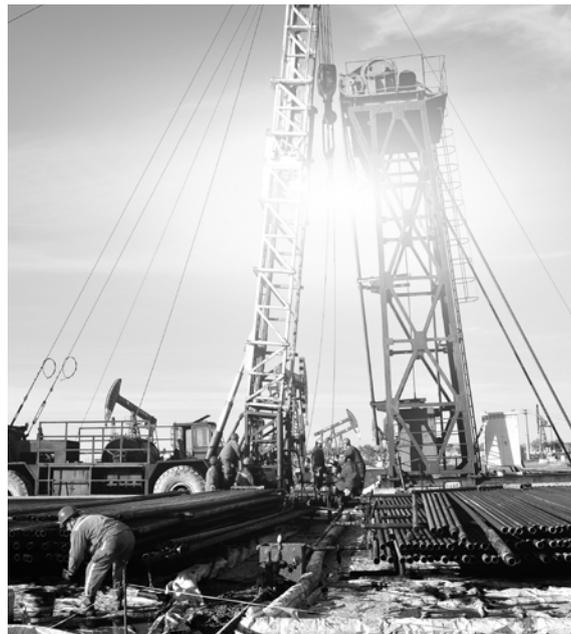
Other relevant physical risks include storms, flooding and sea level rise, increasing temperature levels, and bushfires (Smith, 2016). With the intensity and frequency of such extreme weather events increasing, project developers should account for potential delays in construction or production caused by physical climate stressors, as well as price in asset damage risks.

Export value chain segments are affected specifically by sea level rise, floods, storms, and high temperatures. LNG liquefaction processes require cooling gas to -160°C, meaning that higher ambient temperatures result in higher liquefaction costs (Smith, 2016). Storms can also cause shipping delays, limiting LNG carriers' ability respond to spot market opportunities (Jaganathan, 2020).

3.5 GUIDANCE

Financial support for upstream and export gas projects is not Paris-aligned. Based on the mitigation and adaptation criteria stipulated in the joint MDB alignment framework, DFIs should exclude support to upstream gas projects from eligibility in future investments. Negative externalities are significant, given that new gas reserve development is not compatible with the ever-shrinking remaining carbon budget. There are significant transition risks undermining the export business case, and the development of gas production and export infrastructure reinforces continued fossil fuel dependence. Depending on the local context, physical climate risks are likely to be significant, especially for fracking in water-stressed regions.

Exceptions to the exclusion of gas support are investments with the aim to reduce fugitive emissions and methane leakage in gas extraction, processing, and liquefaction in existing infrastructure (refurbishments, such as monitoring equipment or maintenance to reduce leakage), as long as they do not prolong the asset's lifetime. Support for the decommissioning of upstream value chain infrastructure is another Paris-aligned exception in the sector.



Box 2: Upstream gas project case study

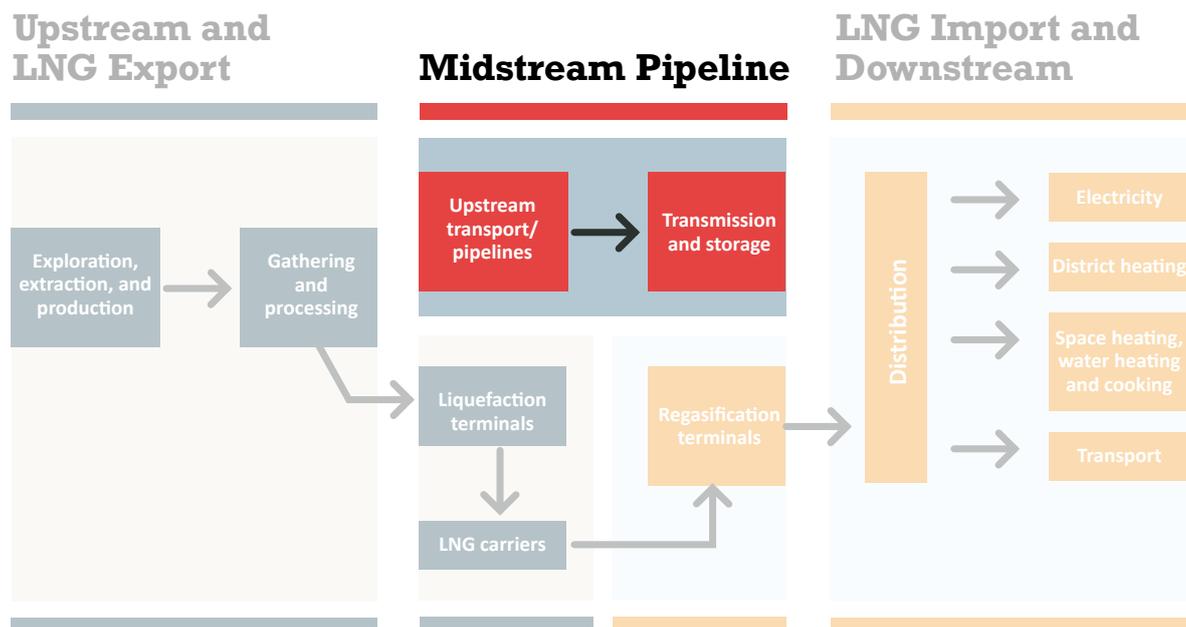
Project name	Country	Region	Signature date	Budget (USD)
Mozambique LNG Area 1	Mozambique	Eastern Africa	11/06/2020	AfDB finance: 400 million Total project cost: 24.1 billion
Description				
The Mozambique LNG Area 1 project consists of the development of an LNG plant with a production capacity of 12.88 million tonnes per annum (MTPA), including offshore extraction, pipeline, gas processing, and liquefaction facilities, as well as an LNG export terminal and other associated facilities. This project represents the largest foreign direct investment (FDI) carried out in Africa to date (AfDB, 2020). The project's objective is to strengthen Mozambique's LNG export capacity, and it is expected to make the country the world's third largest LNG supplier.				
Criteria				
Sector-specific criteria				
Q	Does the project contribute to the objective of reducing global gas generation levels (by at least 3% a year)?			
A	⊗ No. The financing of gas exploration, extraction, and processing activities is inconsistent with this sector-specific criteria.			
Lock-in risks				
Q	Does the project help the country shift to a low-carbon development pathway?			
A	⊗ No. Significant investment in human capital (local training and employment of 5500 workers) and infrastructure (USD 2.5 billion in auxiliary infrastructure investments) locks in specialisation of local companies and workers in the gas extraction sector.			
Q	Does the project help the country avoid unsustainable export dependencies linked to fossil fuel extraction and export?			
A	⊗ No. The economic development of the gas sector and associated revenue are likely to result in currency appreciation, thereby limiting and or undermining other potential export-oriented industries. There is empirical evidence from Mozambique that, in addition to the negative impact of actual inflows of extractive resource revenue, anticipated revenue also leads to negative macroeconomic and political effects, long before resource extraction takes place (Frynas and Buur, 2020).			
Transition risks				
Q	Is the economic feasibility of the project justified (positive net present value (NPV)), despite a constant and rapid decline in demand for gas/LNG on the global market?			
A	⊗ No. The economic justification of the project is built on the assumption that the global demand for gas will increase between 2020 and 2035 (Balderrama, Kinoshita, Obianagha and Achieng, 2019). Gas demand outlooks aligned with the Paris temperature goal assume that gas will peak by 2025 at the latest, followed by a rapid decrease in demand (see Section 3.3). Declining gas demand can result in a potential price collapse, which would generate a risk of stranded assets, as Mozambique LNG Area 1 is unlikely to compete with LNG suppliers from Qatar, Nigeria, and Russia, which can produce and export gas at lower costs (Steuer, 2019). In a 2°C scenario, most LNG projects in Southern Africa would not be needed, whereas in a 1.5°C scenario, even projects whose funding is complete would be unnecessary (Wood Mackenzie, 2020).			
Resilience criteria				
Q	Is the availability of water guaranteed, considering current and future climate impact modelling of drought?			
A	✔ Probably. The project is an offshore plant with lower freshwater requirements than shale gas extraction.			
Q	Is the project designed to minimise water consumption?			
A	(Not applicable.)			
Q	Is the economic feasibility of the plant justified (positive NPV), considering the additional associated costs of resilience measures and the risk of forgone revenue (e.g. extreme weather events delaying exports)?			
A	⊗ No. Mozambique is one of the countries most affected by extreme meteorological events worldwide (ranked first in 2019) (Eckstein, Künzel and Schäfer, 2021). Climate risks such as storms, flooding, and sea level rise can seriously affect the setting up of the production site, delay liquefaction processes in LNG terminals, or cause shipping delays, adversely affecting the economics of the project in the construction and operation phases.			
Investment guidance				
This investment is inconsistent with the Paris Agreement, as it fails to comply with most criteria.				

4. MIDSTREAM PIPELINES

Midstream transmission infrastructure includes domestic and cross-border transmission pipelines, as well as storage capacity. Pipeline gas trade makes up close to 90% of global gas trade (Muttitt *et al.*, 2021). LNG trade, however, has recently grown, as more and more countries are building

import/export terminals. Along with more LNG terminals, the global market for natural gas is also shifting, with importers increasingly interested in more flexible short-term contracts and smaller volumes (Bresciani *et al.*, 2020)—the opposite of the general contract model for pipelines.

Figure 7: Midstream transmission value chain components



4.1 INPUTS FROM PARIS-COMPATIBLE SCENARIOS: SECTOR-SPECIFIC CRITERIA

DFIs' support for the new development of midstream transmission (pipeline) and storage projects contributes to higher levels of gas extraction in exporting countries and gas use in importing countries. Notably, in the IEA Net Zero Scenario, gas trade by pipeline falls by 65% between 2020 and 2050, meaning that much of the existing infrastructure exceeds or will exceed needs (IEA, 2021b). As such, pipeline infrastructure investments are inconsistent with sector-specific Paris alignment criteria, such as the need for global gas production levels to decline by 3% per year between 2020 and 2030 to be aligned with the 1.5°C target (SEI *et al.*, 2020).



4.2 LOCK-IN RISKS

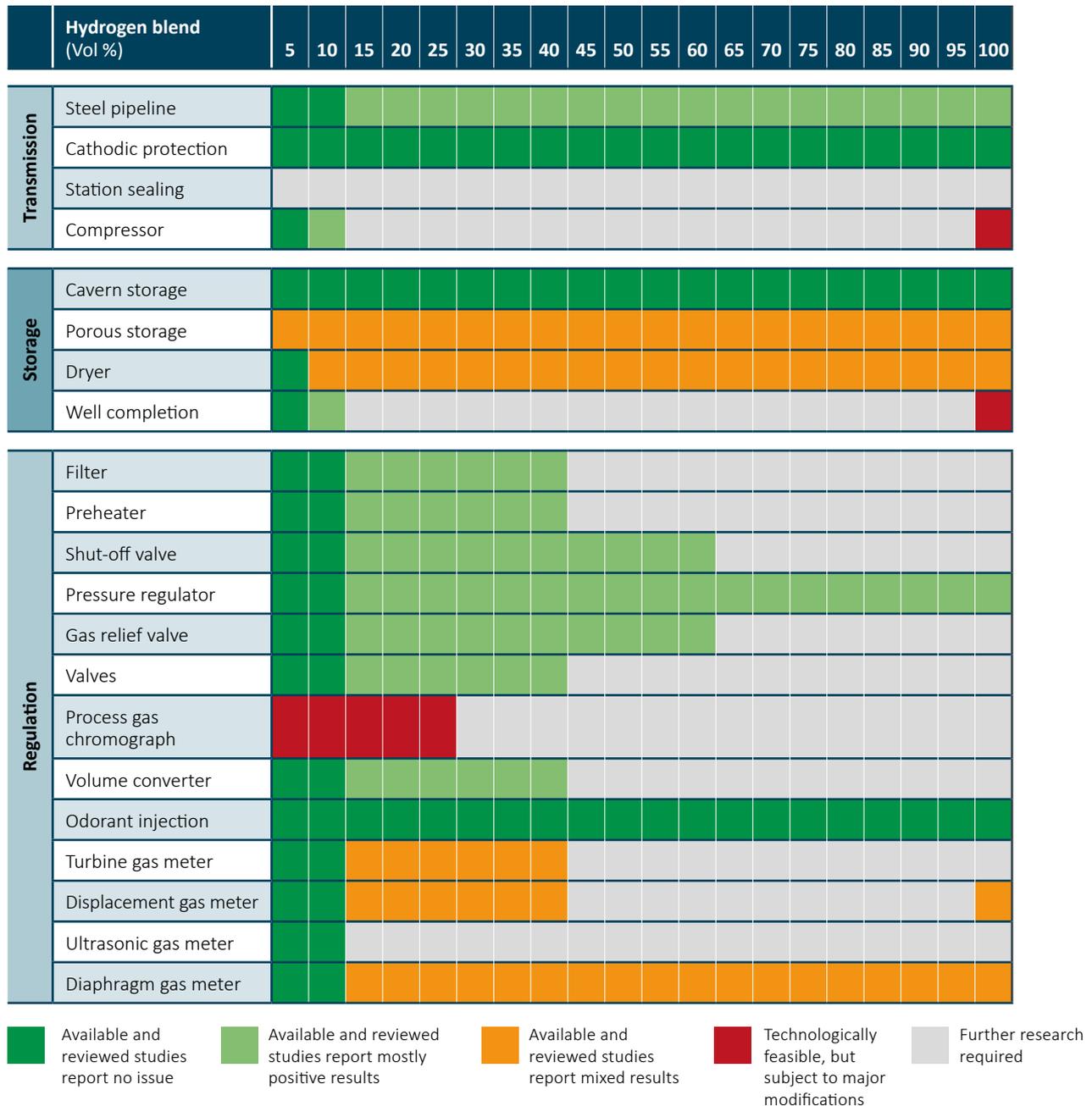
DFIs' support for greenfield midstream gas transmission and storage projects is likely to undermine efforts to transition to Paris-aligned activities. Despite claims that pipeline projects have the potential to be repurposed to transport low-carbon gases such as hydrogen, considering the low feasibility of repurposing infrastructure and the low likelihood that current areas of supply and demand for low-carbon gases will correspond with future areas, pipeline projects pose significant lock-in risks to both buyers and sellers of gas.

Gas pipelines have lifetimes of up to eighty years (Dutton, Fischer and Gaventa, 2017). Hydrogen can be blended into existing natural gas transmission infrastructure only up to a volume level of 10% without major modification of the transmission system (Marcogaz, 2019). Specific parts of the natural gas midstream transmission infrastructure are capable of handling larger shares, or even pure hydrogen (for example, plastic and potentially steel distribution and transmission pipelines, pressure regulators, and cavern storage), while other transmission infrastructure components cannot be repurposed without major modification (see Figure 8) (Marcogaz, 2019). Hydrogen compatibility across end uses is also variable and often uncertain depending on the exact end use; this uncertainty reduces the credibility of repurposing plans for transmission infrastructure.

On a system level, the rationale for repurposing is also affected by geographic considerations – namely where natural gas are produced and fed into the system compared to future sources of low carbon gasses (Vernoit, Malik and Fischer, 2020). Low-carbon gasses, such as biogas or hydrogen, will likely need to be processed and fed in at decentralised connection nodes, which in many cases will need to be newly built. The siting and general viability of low-carbon gas production is further complicated by the need for freshwater resources (hydrogen) or biomass stock (biogas).

Concerns over carbon lock-in risks stemming from pipeline gas transmission infrastructure have been growing. The U.S. Environmental Protection Agency, for example, urged the country's energy regulator (Federal Energy Regulatory Commission) to expand the scope of climate considerations under its pipeline policy framework, including the potential for stranded assets and evaluation of clean energy infrastructure alternatives capable of meeting future energy demand (Paul and Weber, 2021).

Figure 8: Hydrogen blending test results, based on Marcogaz (2019)



4.3 TRANSITION RISKS

Midstream gas transmission and storage projects face significant transition risks, both because of the limited knowledge on the feasibility of gas infrastructure repurposing and the uncertain demand for low-carbon gas in end use applications where electricity is increasingly becoming the most cost-effective energy carrier. Midstream gas transmission and storage projects are therefore generally unviable in a Paris-aligned economic context.

Plans for natural gas transmission infrastructure repurposing do not necessarily align with a country's strategy for the wider energy transition. A country's final demand for low-carbon gases beyond hard-to-abate sectors is highly uncertain. Sectors currently dependent on natural gas infrastructure (e.g. residential heating or cooling and transport) are likely to be electrified as part of their decarbonisation process. Electrification is a more cost-effective means of decarbonisation than gas infrastructure repurposing with low-carbon gases (Ueckerdt *et al.*, 2021). Therefore, new transmission assets run the risk of becoming stranded, as clean technology alternatives increasingly suppress future demand for gas (Paul and Weber, 2021).

There have been multiple cases where pipelines have become stranded before even becoming operational. International transmission pipelines spanning multiple countries or regions face political and reputational risks, where regulatory changes or strong public opposition delay or stop project development. This has been the case with the North Stream 2 Pipeline between Russia and Germany, the Keystone pipeline in Canada and the U.S., and the Guaymas-El Oro gas pipeline in Mexico (Browning *et al.*, 2021). Large pipeline transmission projects have long lead times, due to extensive permitting and environmental safeguarding requirements. Over time, more ambitious climate action can invoke regulatory changes that further limit the development of large gas pipeline transmission projects.

4.4 RESILIENCE

Physical climate impacts pose risks to midstream transmission and, to a lesser extent, storage infrastructure. Flooding, excessive precipitation, sea level rise, and related physical factors can directly or indirectly (e.g. via soil erosion or landslides) damage midstream transmission assets (Jackson, 2018). Pipeline ruptures can cause significant methane leakage, which may remain undetected for some time. Transmission assets at risk (and the corresponding commodity loss) also adversely affect the economics of projects. When taking investment and support decisions, DFIs should account for the physical climate risks and costs and consequences of transmission asset damage.

The overall resilience of a country's energy system is adversely affected when centrally dependent infrastructural elements face significant physical climate risks. Midstream gas transmission and storage infrastructure investments are unlikely to improve countries' adaptive capacity, especially compared to decentralised systems based on decentralised, local renewable energy generation and end use electrification.

4.5 GUIDANCE

Financial support for midstream gas transmission is generally not Paris-aligned. Plans for the repurposing of transmission lines and storage should not justify investments in new natural gas infrastructure, given the lock-in and transition risks resulting from technological uncertainty with respect to repurposing plans and geographic shifts for low-carbon gas production supply and demand. Prone to physical climate risks over long distances, gas transmission and storage infrastructure deployment also does not support countries towards climate resilient development.

Exceptions to the exclusion of gas support are investments that reduce fugitive emissions and methane leakage across midstream natural gas transmission (e.g. monitoring equipment and maintenance). Such measures are often economical, with the saved gas quickly paying for the investment (IEA, 2021a). Retrofits and modification (refurbishment) of existing infrastructure with the aim of gradually repurposing assets with low-carbon gases are also justifiable but should not extend the operational life of assets used for natural gas transmission and storage.

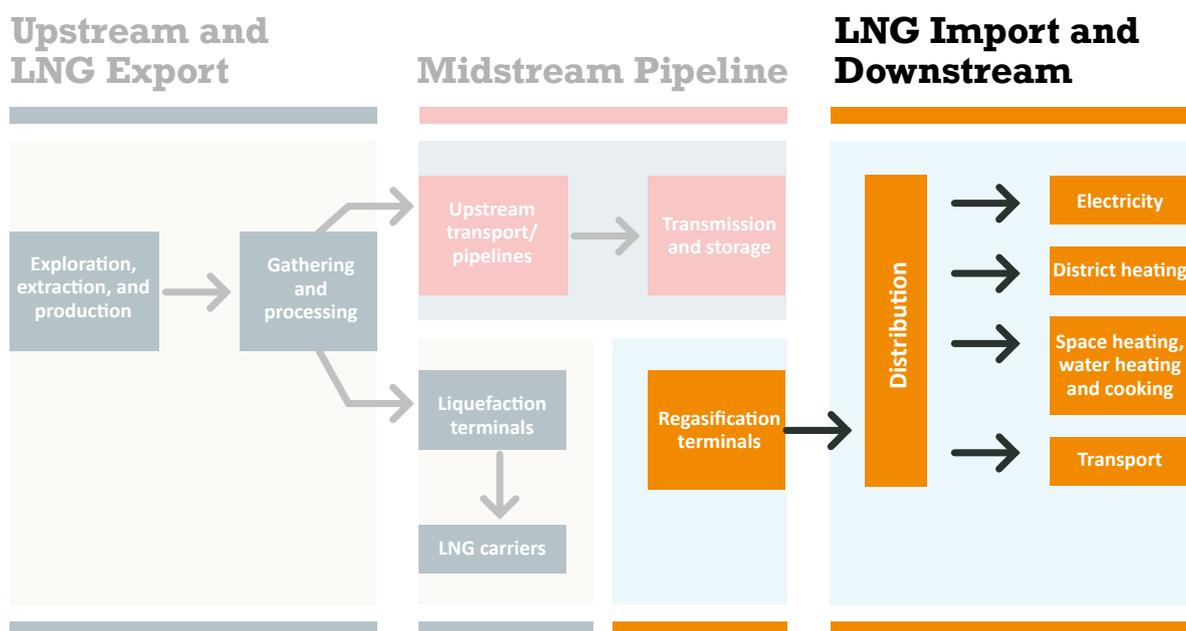
Box 3: Midstream gas pipeline project case study

Project name	Country	Region	Signature date	Amount in US dollars
TAPI Gas Pipeline Project (Phase 1)	Turkmenistan, Afghanistan, Pakistan, India	Central Asia	18 May 2020	ADB finance: USD 1,000 million Total project cost: USD 7,742 million
Description				
The ADB Turkmenistan-Afghanistan-Pakistan-India Pipeline (TAPI) project entails the construction of approximately 1,600 kilometres (km) of gas pipeline. At full design capacity, the 56-inch TAPI pipeline will transport up to 33 billion cubic metres (m ³) of natural gas per year from Galkynysh Gas Field in Turkmenistan to respective buyers in Afghanistan (5%), Pakistan (47.5%), and India (47.5%) over the 30-year commercial operations period. Phase 1 of the project includes the design, procurement, installation, and operation of the pipeline and related facilities in Afghanistan and Pakistan.				
Criteria				
Sector-specific criteria				
Q	Does the project contribute to the objective of reducing global gas generation levels (by at least 3% a year)?			
A	⊗ No. The project promotes higher levels of gas extraction in Turkmenistan and is likely to increase gas use in Afghanistan, Pakistan, and India.			
Lock-in risks				
Q	Does the project help the country shift to a low-carbon development pathway?			
A	⊗ No. The project targets the extraction and combustion of 33 billion m ³ of natural gas per year for a 30-year period, produced in an extraction site that is known to have methane leakage rates high enough (4.1%) to result in little to no environmental benefit over coal (Schneising <i>et al.</i> , 2020).			
Transition risks				
Q	Does the project lead to the gradual repurposing of existing gas transmission infrastructure for use with low-carbon gases? Is it technologically feasible to completely repurpose the transmission asset?			
A	⊗ No. Repurposing plans have not been officially disclosed, and the technical feasibility of fully repurposing the TAPI pipeline is unclear.			
Q	Is it clear that the assets will not become stranded? Is this still the case where the electrification of most sectors results in rapidly declining demand for gas? Is this still the case where decentralised siting of low-carbon producers and offtakers requires modifications/extensions of the existing assets?			
A	⊗ No. It is not clear whether demand for gas, whether natural or low-carbon, from Turkmenistan will stay at the same level over the project lifetime, given the cost-competitiveness of renewable energy (Pakistan, for example, has recently announced ambitious plans for solar photovoltaics (PV)). It is also likely that pipeline repurposing would require significant extensions or modifications to accommodate the siting of low-carbon gas producers and consumers.			
Resilience criteria				
Q	Are the transmission assets resilient against physical climate impacts?			
A	⊗ No. Flooding, excessive precipitation levels, sea level rise, and related physical factors can directly or indirectly (e.g. via soil erosion and landslides) damage midstream transmission assets (Jackson, 2018), and no strategies have been disclosed regarding building adaptive capacity.			
Q	Will the project strengthen the resilience of the affected country's energy sector?			
A	⊗ No. The pipeline represents a centralised transmission asset and will likely undermine countries' energy security and resilience.			
Investment guidance				
This investment is inconsistent with the Paris Agreement, as it fails to comply with most criteria.				

5. LNG IMPORT AND DOWNSTREAM

The gas midstream import and downstream value chain grouping includes regasification terminals for LNG imports, gas and LNG distribution to end use sectors, and key end uses, such as electricity generation, district heating, space heating, water heating and cooking, and transport.

Figure 9: Midstream import and downstream value chain components



5.1 LNG IMPORT

LNG import terminals include onshore and offshore (floating) storage and regasification units. Imported LNG is stored in large tanks before it is vaporised via sea water heat exchangers, air vaporisers, or gas-fired combustion vaporisers (Agarwal *et al.*, 2017). Floating regasification plants are growing in popularity due to their lower capital investment requirements, lower lead times (2-3 years from project concept to implementation), and ability to relocate (Gomes, 2020).

5.1.1 Inputs from Paris-compatible scenarios: Sector-specific criteria

Considering the lack of a complete categorical exclusion for various gas end uses (see Section 5.2, 5.3), sector-specific criteria on LNG import infrastructure is not entirely clear. For example, the IEA Net Zero Scenario expects any additional LNG export capacity to be at high risk of becoming stranded, but not necessarily LNG import terminals. The climate impact of additional LNG infrastructure in general, as well as the specific impact of LNG import infrastructure, should not be underestimated. LNG infrastructure is especially harmful to the climate; because of the associated fugitive emissions and high energy requirements for liquefaction, marine transport, and regasification, LNG lifecycle emissions can be twice as high as those of domestic gas (Muttitt *et al.*, 2021).

5.1.2 Lock-in risks

Greenfield LNG import terminals are likely to contribute to a lock-in to gas dependence for all end uses in a given country and therefore undermine the transition to a Paris-aligned trajectory.

Developing and emerging countries facing growing energy consumption levels should make every effort to leapfrog gas-based energy systems. The development of LNG import infrastructure is likely to lead to lock-in on both a physical infrastructure and political/policy level. LNG import infrastructure is associated with further infrastructural needs, including transmission, distribution, and storage equipment (Bresciani *et al.*, 2020). Establishing LNG infrastructure is likely to create a lobby that will advocate for continued gas use in various end uses to justify the sunk costs of LNG import infrastructure development. For developing countries with constrained capital resources, this reduces finance for and crowds out opportunities to shift directly to clean energy alternatives.

Considering the technological uncertainty and increased costs to convert LNG import infrastructure for use with low-carbon gases such as hydrogen (see Figure 8), there is a high risk that such infrastructure would be stranded in a rapid low-carbon transition.

5.1.3 Transition risks

LNG import infrastructure is subject to significant transition risks, given the uncertainty regarding LNG demand and the commodity's price level.

Low LNG price levels can render gas-fired electricity or heat generation attractive in emerging and developing countries. However, price levels are volatile and difficult to predict for the medium and long term, as both LNG demand and supply face significant uncertainties. On the demand side, the cost advantage of renewable energy, with essentially zero marginal costs in the downstream sector, is rendering gas-fired electricity and heat generation increasingly unattractive. The relative cost advantage of renewables is likely to increase over time. In contrast, the operating costs associated with gas extraction, LNG liquefaction, transport, and regasification will reach lower limits below which exporting countries will stop exporting, as prices drop below break-even levels (Steuer, 2019).

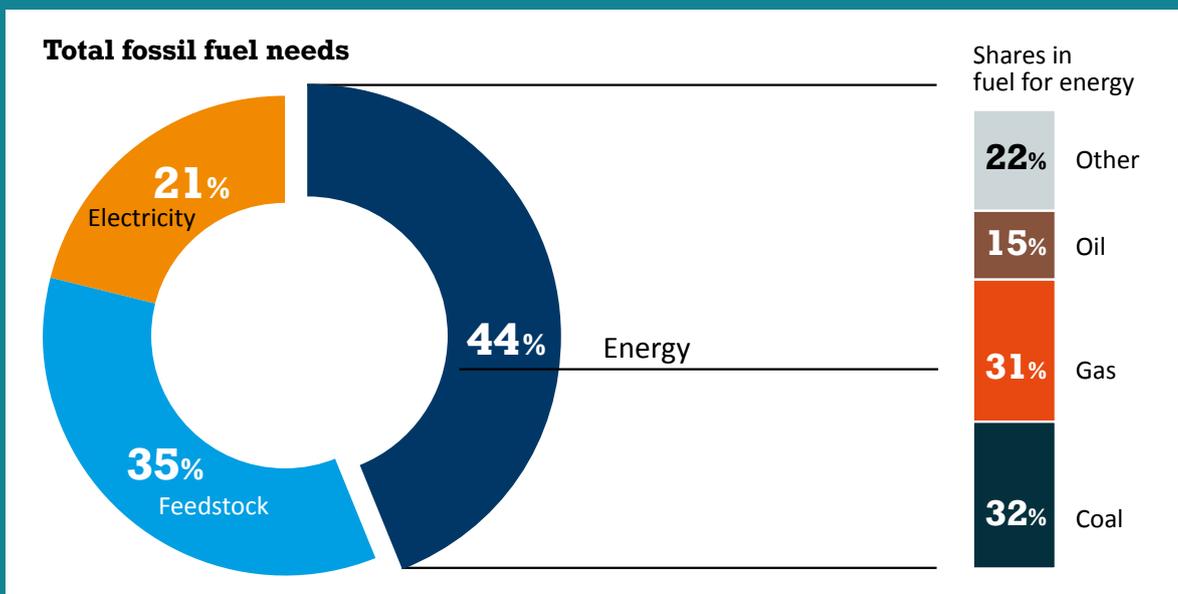
Given long lead times, the need for domestic LNG transmission and distribution infrastructure, and the improbability that imported LNG as an energy carrier will be able to compete with renewable energy-based electricity, LNG import terminals run a serious risk of being underutilised in the medium term (Choksey and Richter, 2021) and consequently becoming stranded assets. In light of the growing demand to consider and take measures to reduce the carbon intensity in trade policy—for example the proposed European carbon border adjustment mechanism—the diffusion and adoption of gas-fired technology in industry associated with the development of LNG import infrastructure can adversely affect the competitiveness of developing and emerging countries' exports. As energy is a key input, energy security and affordability are priorities for the industrial sector. DFIs should ensure that LNG import infrastructure projects do not jeopardise a country's industrial sector's competitiveness, neither now nor in the near future, when emissions intensity is likely to be a larger factor in trade (see Box 4).

Box 4: Electrification of the industrial sector

Fuel for energy accounts for the largest share of fossil fuel consumption in the industrial sector (see Figure 10), such as for the generation of industrial heat. For low- to medium-temperature heat, such as that required in drying, evaporation, distillation, and activation processes, electricity-based technologies are commercially available. It is technologically feasible to employ electric boilers and furnaces to electrify up to an estimated 50% of industrial processes (McKinsey & Company, 2020a). Falling electricity prices and the prospect of carbon pricing schemes will make the electrification of many industrial processes economically attractive. For processes demanding high-temperature heat, such as steel production, green hydrogen, or other alternative low-carbon fuels can replace gas. DFIs have

the potential to play an important pioneering role in supporting full industrial decarbonisation in developing countries by investing in such low-carbon alternatives—especially considering their excellent renewable energy potential (Englert *et al.*, 2021). Current investment considerations should avoid supporting projects that damage the competitive advantage of developing countries’ export-oriented industries, especially with carbon border adjustment measures being discussed in a number of importing countries. In June 2021, a leaked proposal from the European Commission indicated that the first industries to be targeted by the EU’s carbon border adjustment mechanism would include steel, iron, cement, fertilisers, aluminium, and electricity (Taylor, 2021).

Figure 10: The role of gas in the industry sector, based on McKinsey & Company, 2020a



5.1.4 Resilience

LNG import infrastructure is vulnerable to a number of physical climate risks, including storms, flooding, and sea level rise (Smith, 2016). With the intensity and frequency of extreme weather events increasing, project developers should factor in potential delays in construction or operation caused by physical climate stressors, as well as price in asset damage risks. Onshore LNG import terminals are built in shoreline proximity and are hence specifically affected by sea level rise, flooding, and extreme winds. Storms can also cause shipping delays, limiting LNG carriers’ ability to meet gas demand.

5.1.5 Guidance

The joint MDB Paris alignment approach includes sector-specific assessment criteria, as well as consideration of lock-in risks, transition risks, and physical climate risks⁶. The alignment approach, however, does not allow for a complete categorical exclusion of LNG import infrastructure. As an input to the Paris alignment considerations, we therefore propose a number of specific questions that can help a DFI in decision-making on whether to support or decline support for a project based on its consistency with the Paris Agreement.

⁶ (In)consistency with countries’ NDCs and LTSs is also part of the framework but not further explored here.

If any of the following questions is answered with a no, the project is likely to undermine the achievement of the Paris Agreement objectives. The proposed criteria set a high bar for the justification of (limited) exceptions, which are likely to be extremely rare if the criteria are robustly applied.

Sector-specific criteria:

- Is it clear that the development of new LNG import infrastructure will not undermine the decarbonisation pathway implied by the sector-specific criteria of planned end uses, i.e. electricity generation, combined heat and power, and industrial use?

Lock-in risks:

- Is it clear that the development of new LNG import infrastructure will not undermine incentives to shift towards zero- and low-carbon alternatives?
- Is it clear that investments in LNG import infrastructure will not crowd out investments in economically viable and technologically feasible alternatives?

Transition risks:

- Is it clear that newly developed LNG import infrastructure is economically viable in a scenario with rapid building electrification and expansion of renewable electricity generation?
- Is it clear that newly developed LNG import infrastructure will not jeopardise a country's industrial sector's competitiveness, both currently and considering future climate considerations in trade policy?

Resilience/physical climate risk:

- Is the LNG import infrastructure resilient against physical climate impacts?
- Will the project strengthen the resilience of the country's energy sector?

5.2 ELECTRICITY GENERATION

Until recently, gas has played a large and growing role in global electricity production, reaching over 23% in 2018 (IEA, 2020e). In developing and emerging countries, 17% of electricity generation is gas-fired (Muttitt et al., 2021). However, electricity systems in many countries are approaching transformation points. The exponentially falling cost of renewable energy and energy storage technology are defining a new default approach to electricity generation (Climate Action Tracker, 2019). Additionally, the onset of the COVID-19 pandemic, associated reduction in energy demand, and unprecedented expansion of renewable energy have important implications for the future of gas in the power sector.

In the electricity system, gas power plants can take on the role of baseload generators, load following generators, and peaking power plants. Combined cycle gas turbine (CCGT) plants traditionally provide baseload and load following services, have generally relatively large capacities, and represent major nodes in centralised electricity grids. These plants are the most efficient in terms of emission intensity per kilowatt-hour (kWh), but generally lack the flexibility to quickly ramp up or down.

Open cycle gas turbines (gas combustion turbines, or OCGTs) traditionally serve as peaking power plants that can quickly be brought online to meet short-term increases in electricity demand. Peaking plants are usually comparatively smaller and are connected to the distribution network in a decentralised manner, rather than serving as nodes in the main transmission grid. As peaking power plants are designed to only run for short periods during peak demand times, they tend to have lower thermal efficiency and higher emission intensity than CCGTs.

Box 5: Energy access and fossil fuels

In 2020, almost 790 million people lacked access to electricity, mostly in Sub-Saharan Africa (UN, 2020). Electricity access is a central development objective, given its importance in advancing progress on a broader set of sustainable development goals. Renewable energy technology is best suited to ensuring access to clean, reliable, and affordable electricity, broadly eliminating the need for gas-based generation in the sector.

Countries with large energy access gaps are primarily located in Sub-Saharan Africa and Asia (IEA *et al.*, 2021). The practical renewable energy potential, specifically from solar PV, in most countries facing large access gaps is immense and by far exceeds current electricity demand (ESMAP, 2020a). While practical potentials are high, the levelised cost of electricity (LCOE) and land use requirements tend to be low. However, countries often lack favourable regulatory frameworks, incentive schemes, and adequate national electrification planning (as measured through low Regulatory Indicators for Sustainable Energy (RISE) scores), which are required to rapidly scale up the deployment of renewable energy solutions (see Figure 11).

DFIs should assist developing countries in identifying the most suitable, cheapest, and least polluting electrification approach. The expansion of gas-fired generation capacity and extension of electricity grids to rural areas is often not the fastest, cleanest, or most economical option (Blechinger *et al.*, 2019). Centralised grid extension approaches are also often not comprehensive; large populations in urban and peri-urban areas in Sub-Saharan Africa are living “under the grid” (Graber, Mong and Sherwood, 2018), i.e. in the proximity of existing transmission infrastructure but without (reliable) electricity connections.

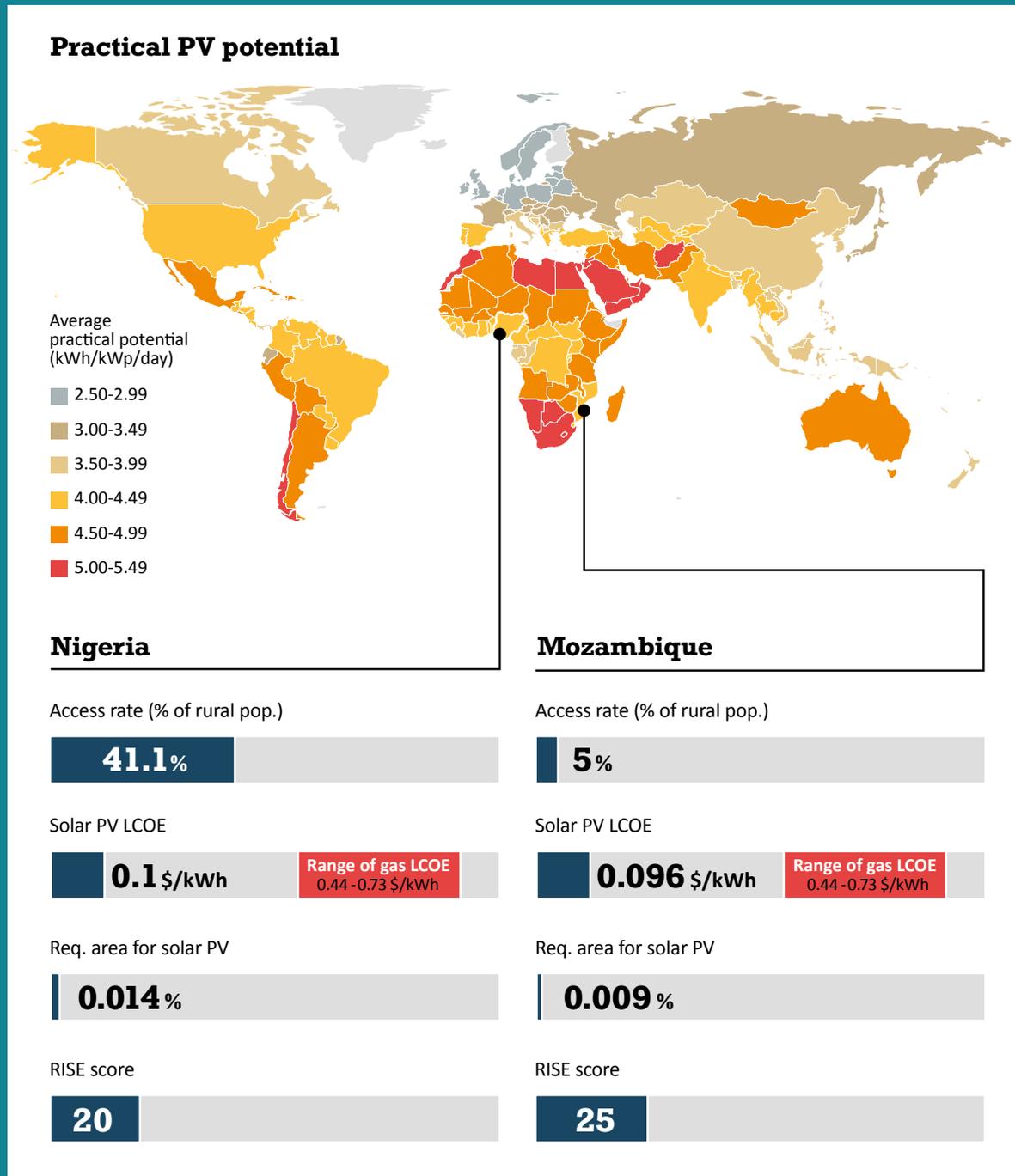
Renewable energy mini-grids or standalone solar PV systems can be deployed much faster and can provide access to electricity (at Tiers 2 and 3, as defined by the Energy Sector Management Assistance Program’s (ESMAP) Multi-Tier Framework (MTF) energy access measurement methodology) more cost-competitively and inclusively and with important co-benefits for rural livelihoods (Blechinger *et al.*, 2019). Specific studies show this to be the case in Sub-Saharan Africa in general (Dagnachew *et al.*, 2017) and specifically in Kenya (Moner-Girona *et al.*, 2019) and in the Philippines (Bertheau and Cader, 2019).

The large-scale deployment of off-grid renewable energy solutions would allow developing countries to leapfrog fossil fuel-based electricity generation for unconnected populations, which is consistent with DFI climate action commitments and the energy transition in developing countries more generally. Energy modelling shows that 100% renewable energy systems are cheaper than fossil fuel-based alternatives, as fuel cost savings more than compensate for upfront capital investments in a large number of contexts, both in developing and developed countries (Aghahosseini *et al.*, 2019; Fünfgelt and Skowron, 2020). Countries with ample renewable resource potential (such as those in Sub-Saharan Africa, and most least developed countries (LDCs) and small island developing states (SIDS)) are further unlikely to need storage capacities of more than 10-20% of total energy generation by 2050 (Fünfgelt and Skowron, 2020).

Deployment of new gas-fired generation is not only likely to delay developing countries’ energy transitions, but it also subjects countries to readily avoidable transition risks that can have economy-wide impacts. For example, where countries depend on imported gas (*e.g.* LNG), high commodity prices over an extended period can put a strain on developing countries’ foreign currency reserves and result in volatile trade terms.

Insufficient or unfavourable regulatory support for sustainable energy is often the predominant barrier to fast and universal deployment of renewable energy solutions in countries with large access gaps and low energy security (ESMAP, 2020b). DFIs should support developing countries in establishing comprehensive national electrification and energy transition frameworks. These frameworks should promote the deployment of renewable energy solutions and provide incentives for private investors, while simultaneously ensuring affordability for end users. Gas-fired generation must be avoided where renewable energy alternatives exist for new power plants to be consistent with countries’ decarbonisation imperatives.

Figure 11: Practical PV potential, electricity access rates, economic potential, and RISE scores, based on ESMAP (2020a) and ESMAP (2020b)



5.2.1 Inputs from Paris-compatible scenarios: Sector-specific criteria

The overall extremely limited and shrinking carbon budget, the associated required rate of overall GHG emission reductions, and the necessity to reduce methane emissions from related infrastructure indicate that there is extremely limited potential for expansion of gas-fired electricity generation. The lifetime of a gas turbine can be 30-40 years or more (Duquiatan, 2019). The IEA's Net Zero Scenario calls for decarbonisation of advanced economies' electricity by 2035 and that of emerging markets and developing countries by 2040 in order for other sectors to decarbonise through electrification (IEA, 2021b). This means that a power plant built in the early 2020's must either be shut down or undergo costly retrofitting to run entirely on zero-carbon alternative fuels long before the end of its potentially useful life.

Sector-specific benchmarks on the global level provide life cycle emission standards and scenarios for the share of gas in the electricity mix compatible with temperature targets of 1.5°C/well below 2°C⁷ (see Table 4).

CCGTs, depending on their capacity, are estimated to have an emission intensity of 325-488 grammes of CO₂ equivalent (gCO₂e) per kWh (IFC, 2017). OCGTs have higher per unit emissions, 448-673 gCO₂e/kWh (IFC, 2017). Based on the global benchmarks provided, expanding electricity generation capacity with gas-fired generation plants is broadly incompatible with the Paris temperature targets.

Gas, however, can play various roles in electricity generation, from baseload to flexible peaking power plant capacity (see Table 5). From a system level perspective, in extremely exceptional cases where demand and supply balancing and other ancillary grid services are not yet feasibly or reliably provided by renewables and there is a lack of appropriate grid management or electricity storage technologies such as lithium-ion (Li-ion) batteries, small-scale gas-fired peaking plants may contribute to stability in a grid with high renewables penetration (>10%, see Muttitt *et al.* (2021)). This enabling role of gas to support renewable integration is usually not adequately reflected in global benchmarks and should be evaluated on a per case basis (i.e. accounting for the penetration of renewables in a given electricity system, among other things). In summary, the benchmarks on the sectoral level are not in and of themselves sufficient to categorically exclude individual gas peaking plant projects.

The cited benchmarks do however underline the need for a rapid decline and phase out of fossil fuels. Specifically, these benchmarks show that every additional gas power plant that can feasibly be avoided must be avoided. Any exempted support for the development of new gas-fired generation should follow and support the primary objective of providing energy access while progressively decarbonising electricity generation on a sectoral level by 2050 (De Vivero-Serrano et al., 2019).

⁷ With limited or no overshoot and minimising negative emissions technology.

Table 4: Paris-compatible benchmarks

Benchmark	Type	Threshold	Description
<i>Climate Action Tracker Paris Agreement 1.5°C-Compatible Benchmarks</i>	Lifecycle emission standard	50-125 gCO ₂ e/kWh by 2030 5-25 gCO ₂ e/kWh by 2040 0 gCO₂e/kWh by 2050	Paris Agreement-compatible benchmarks for global emission intensity standards for the electricity sector, based on a synthesis of regional benchmark estimates (Climate Action Tracker, 2020).
<i>EU Technical Expert Group on Sustainable Finance</i>	Lifecycle emission standard	100 gCO ₂ e/kWh, declining to 0 gCO₂e/kWh by 2050	The threshold is based on EU emission targets for the energy sector, divided by the expected evolution of electricity demand (TEG, 2020).
<i>IPCC 1.5°C pathways</i>	Electricity generation scenario	24.39% (35.08%, 11.80%) in 2020 28.18% (37.23%, 1.75%) in 2030 6.93% (24.87%, 0.00%) in 2050	Median (maximum, minimum) share of gas in electricity generation (%) across 1.5°C-compatible pathways with limited or no overshoot (IPCC, 2019).

5.2.2 Lock-in risks

Depending on their size and planning, investments in gas-fired electricity generation are subject to significant lock-in risks, especially where support to gas-fired electricity generation prevents or reduces market opportunities for zero-carbon alternatives based on renewable energy, demand response, and storage.

Support to conventional baseload plants is inconsistent with the objective of increasing the share of variable renewable energy in a country's power mix. The development of new baseload gas plants and the need to run baseload plants at constant and high utilisation rates in order for them to justify their upfront development costs undermines the integration of higher shares of variable renewable energy generation, representing an acute carbon lock-in risk (IRENA, 2015). The development of new gas-fired electricity generation may have the potential to displace coal-fired generation, but would also crowd out renewable energy, storage, and other flexibility options, most of which are already cost-competitive (Muttitt *et al.*, 2021). Instead, as part of the power system transformation towards full decarbonisation, DFIs should ensure that higher shares of renewable energy generation with feed-in priority will increasingly displace inflexible fossil fuel-based baseload generators (REN21, 2017).

Support to gas-fired peaking power plants in the presence of economically viable and technologically feasible storage solutions can further prolong the need for conventional thermal power plants for ancillary grid services, such as inertia and reactive power (ReCharge, 2021). In the absence of storage capacity, this can result in a situation where electricity system operators remunerate renewable energy generators for curtailment, while simultaneously paying for and keeping online gas-fired generators for the ancillary services they provide – a double payment that can be avoided through sufficient storage capacity.

Smaller and more responsive peaking power plants close to centres of electricity demand (generally smaller steam turbines and combustion turbines) are more compatible with a growing number of variable renewable energy-based power plants (Bullard, 2020), but are only required to enable the integration of larger shares of renewables where the penetration of variable generation in the electricity mix is already high. As such, lock-in risks may be significantly lower for gas-fired peaking plants, although, depending on the electricity market design and other regulatory factors, they may still reduce the potential attractiveness of zero-emission options.

Table 5: The role of gas in the power system, based on Nelder (2012) and Bullard (2020)

Role in power system	Kinds of power plants	Alternatives	Lock-in risk
Baseload (operate 70-90% of the time – only shut down for maintenance)	Combined cycle natural gas, coal, and nuclear	Progressively incompatible/ obsolete in systems with growing renewable penetration	High: major obstacle to the integration of renewables
Intermediate/load following (operate 30-50% of the time)	Typically OCGTs (to a limited extent, also CCGTs, coal, and nuclear)	PV & wind, in combination with Li-ion batteries; pumped hydropower; concentrating solar power (CSP); demand response programmes (smart grids); time of use pricing; increased grid interconnections	Medium/low
Peaking (operate only for short periods, e.g. a few hours a day)	OCGTs or oil-fired turbines	Li-ion batteries; demand response programmes (smart grids); time of use pricing; increased grid interconnections	Low

5.2.3 Transition risks

Gas-based electricity generation – both baseload and peaking power plants – is subject to significant transition risks, given the rapidly improving cost-competitiveness of alternatives. The cost of renewables has decreased drastically; solar PV and onshore wind have essentially zero marginal costs, and their construction and operating costs are lower than those of fossil fuel-based power plants in electricity markets accounting for two thirds of the global population (BNEF, 2020b). In terms of the LCOE,⁸ electricity generated from new wind and solar PV projects is increasingly cheaper than electricity generated in fully depreciated coal and gas power plants (Lazard, 2020a).

As higher shares of cheaper renewable energy reduce the capacity factor (utilisation rate) of gas power plants,

baseload plants (principally CCGT) in particular are already often stranded as their revenue streams decline. Lazard’s estimates assume capacity factors of 55-70%, but Robertson and Mousavian (2021) cite examples of steeper declines and anticipate more in the future. Gas power plants are increasingly forced into stabilising load following or peaking roles in the energy system. For CCGTs, such flexible duty modes lead to higher operation and maintenance (O&M) costs due to mechanical fatigue (Espinoza and Carson, 2014). The high transition risks associated with new gas-fired baseload capacity mean that support for CCGT plants is not Paris-aligned. The transition risks of gas-fired peaking plants are also significant. Their support should therefore be assessed more critically considering existing alternatives.

⁸ LCOE is defined as the net present value of the average total cost of building and operating the asset per unit of total electricity generated over the asset’s lifetime (CFI, 2021). It reflects the cost of electricity produced from a specific technology, taking into account the plant’s useful life, capital costs, and O&M costs, such as the cost of fuel where applicable, in present value terms (Timilsina, 2020). In Lazard’s estimates, a capacity factor of 10% for gas peaking power plants is used.

The LCOE represents a benchmark that can be used to compare the cost-competitiveness of different generation technologies, although it is important to keep in mind the differences between variable renewable energy sources such as wind and solar and “dispatchable” sources such as gas plants, some hydropower plants, and storage (Rubert et al., 2019).

Table 6: Gas-based electricity generation and its alternatives, based on Lazard (2020a) and Lazard (2020b)

Technology	LCOE (USD/MWh)	Fuel cost assumption (USD/MMBTu)	Estimated capacity factor	Intermittent	Peaking	Load following	Baseload
CCGT (baseload)	44-73	3.45	55-70%			✓	✓
CCGT* + CCS (baseload)	74-107	3.45	55-70%			✓	✓
Utility-scale solar PV	29-42	-	21-34%	✓	?	✓	?
Wind (onshore)	26-56	-	38-55%	✓	?	✓	?
Standalone storage, 4 h capacity (Li-Ion)	132-245	-	-		✓	✓	✗
Storage, 4 h capacity (Li-Ion) + solar PV	81-124	-	-		✓	✓	✓
Peaking power plant (OCGT)	151-198	3.45	10%		✓	✓	
Peaking power plant (OCGT)** + CCS	190-245	3.45	10%		✓	✓	

Note: The comparison of LCOE is only indicative of the value added by different technologies, as the technologies' services are different from a system level perspective.

* Emission assumption of 0.33-0.37 tCO₂e per megawatt-hour (MWh), based on Lazard (2020a). CO₂ capture cost assumption of USD 91 per tonne CO₂, based on Muratori et al. (2017).

** Emission assumption of 0.4-0.52 tCO₂e/MWh, based on Lazard (2020a). CO₂ capture cost assumption of USD 91 per tonne CO₂, based on Muratori et al. (2017).



In order for electricity systems to function reliably, electricity generation and transmission assets must provide bulk energy, ancillary, transmission, distribution, and customer energy management services (see Figure 12). In addition to the need to balance electricity demand and supply through flexibility reserves, system operators must also ensure the provision of key ancillary grid services, such as (i) system stability via the correction of short-term imbalances (synchronised regulation), (ii) the capacity to respond to unexpected component outages through contingency reserves, and (iii) provisions that allow for the electricity system to perform black-starts in the unlikely event that the entire grid loses power (IRENA, 2017).

Figure 12: Required grid services and the role of storage, based on IRENA (2017)

Bulk energy services	Ancillary services	Transmission services	Distribution services	Customer energy management
Electricity supply shift	Regulation	Transmission upgrade deferral	Distribution upgrade deferral	Power quality
Electric supply capacity	Contingency reserves	Transmission congestion relief	Voltage support	Power reliability
	Voltage reserves			Retails electricity supply shift
	Black-start			Demand charge management
				Self-consumption of solar PV

Highlighted boxes:
Storage solutions enable integration of higher shares of variable renewable energy

Renewable resources such as solar PV and wind, although variable by nature, can fully replace dispatchable fossil fuels when coupled with sufficient storage capacity or some combination of storage, grid interconnections to other areas, demand response measures, and potentially other incentives such as time of use pricing. Many countries in the Global South often have an advantage regarding renewable energy; tropical countries in particular have greater solar irradiation consistency throughout the year, reducing or eliminating the need for long-term/seasonal storage (Muttitt *et al.*, 2021).

The inertia and reactive power of fossil fuel-based generation is also no longer a precondition for reliable electricity grids. Coupled with sufficient storage capacity, renewables can accommodate for synchronised regulation, provide contingency reserves, and ensure system restoration capacity (IRENA, 2017).

Falling technology costs for both renewable energy and (short-, medium-, and long-duration) storage have considerably enhanced the economics of such solutions, with renewable energy plus storage starting to be cheaper than gas peaking plants—which would traditionally provide most of the grid ancillary services—in a rapidly growing number of cases. The LCOE of Li-ion battery storage systems has decreased by about 50% over the last two years (76% since 2012) (BNEF, 2020c), giving battery storage systems a cost advantage over OCGTs in the role of short-term flexible or contingency reserves (assuming battery capacity for up to two hours) (BNEF, 2020c). In Australia, battery storage is 30% cheaper than peaking power plants (Colthorpe, 2021). Furthermore, economies of scale in the production of Li-ion batteries is quickly pushing the two-hour threshold to four hours (Cole and Frazier, 2019). This is not only the case in developed countries; utility-scale solar plus battery storage projects are also being developed in Sub-Saharan Africa (IEEFA, 2021).

For storage of large amounts of electricity for longer than four hours, Li-ion batteries are currently considered too expensive. Only limited economies of scale are possible when extending the capacity of Li-ion battery packs, such that storage capacity beyond 4-6 hours is currently regarded economically unfeasible (Schmidt *et al.*, 2019). Medium-duration storage solutions (with discharge durations of between a few hours and a few days), such as liquid-air and thermal solutions, can be deployed to avoid electricity curtailment in times of high supply and for flexibility reserves beyond the Li-ion battery storage capacity. With appropriate pricing for ancillary grid services, such technologies are already cost-competitive, but many countries lack the regulatory frameworks for the integration of medium-duration storage (ReCharge, 2021).

For long-duration storage needs, such as for seasonal storage, the lack of consideration of the provided grid services in remuneration schemes on a per kWh basis renders storage solutions especially expensive. The need for seasonal storage to balance energy supply and demand, however, is likely to be small, as medium-duration storage systems can provide supply shifts for sufficiently long discharge durations (DNV GL Energy, 2019). Nonetheless, seasonal storage in the form of compressed hydrogen generated from renewables could become cost-competitive with gas-fired long-term reserve capacity in some contexts by 2050 (DNV GL Energy, 2019).

In the shrinking number of cases where renewable energy plus storage systems are not yet cheaper than fossil fuel-based alternatives,⁹ they are likely to become cost-effective fast enough to put the economic justification for gas power plants into question. DFIs should support developing countries through financial and technical assistance focused on driving integrated energy transitions and progressive electricity market reforms to promote the integration of higher shares of variable renewable energy.

When comparing the cost-competitiveness of alternative technology options, DFIs should take a conservative approach that adequately reflects transitional risks, as well as the DFIs' potential to foster transformative change. Technologies with lower maturity tend to have higher perceived risks and face a higher weighted average cost of capital (WACC) than technologies already established in a given context. As providers of capital and technical expertise, DFIs should use financial instruments such as currency swaps, guarantees, and first-loss quasi-equity to bring down the WACC for renewable energy and storage and apply corresponding discount rates in the evaluation of clean alternatives' cost-competitiveness.



⁹ Generally, only in countries with significant domestic supplies of natural gas.

Box 6: DFIs and transformative change

Given the imperative to decarbonise countries' economies as quickly as possible, it is essential to scale up the deployment of alternative clean technologies and, in particular, help clean energy project proponents manage and overcome regulatory and currency risks. Where clean alternatives are not yet economically attractive or technically mature, DFIs have an important role to play in supporting research and development (R&D) and deployment and fostering international technology transfer.

DFIs are in a position and have the responsibility to incubate and upscale transformative solutions that reduce the need for further fossil fuel investments. DFIs are key to ensuring balanced support along the three dimensions of the energy trilemma (energy security, energy equity, and environmental

sustainability), specifically where technological, structural, or economic barriers exist. Where DFIs actively promote transformative change via the provision of financial support and technical assistance for clean technology deployment, developing countries can contribute to global efforts to cut emissions and simultaneously make progress towards achievement of Sustainable Development Goal (SDG) 7.

DFIs should specifically prioritise renewable energy deployment, such as significant solar PV, wind, and storage capacity expansion, in developing countries. Following the decarbonisation of the power sector, the near-full electrification of end uses, *e.g.* in the residential, transport, and industrial sectors, should be a priority for development finance support.



Box 7: Carbon capture and storage

Carbon capture and storage (CCS) technologies capture and store CO₂ released in fossil fuel combustion, thereby reducing but not eliminating direct emissions. In the majority of energy sector development scenarios, and even in some of the IPCC's (2018a) 1.5°C mitigation pathways, CCS deployment is assumed to play at least some role, particularly in combination with natural gas.

CCS technology is however not yet mature. The energy required in the CCS process greatly reduces power plant efficiency, thus significantly increasing costs. This generally makes **them economically unfeasible compared to zero-carbon alternatives**. Gas infrastructure with CCS (newly built or retrofitted) reduces CO₂ emissions by a maximum of 90% (but does not reduce emissions from leakage in gas transport), at around USD 90 per tonne of CO₂ (Muratori et al., 2017). Lifecycle emission reduction potentials are moderate for gas in the power sector, while the LCOE is significantly higher. These cost dynamics have not improved over the past few years, and gas plus CCS looks increasingly unattractive compared to renewable energy and storage alternatives (Hiremath, Viebahn and Samadi, 2021).



In extremely exceptional cases, support for gas-fired peaking plants may be justified if it can be proven that renewable energy, expanded grid interconnections, storage solutions, time of use pricing, and demand response options are incapable of providing the required power stability over the lifetime of the project, including planning, permitting, and the running lifetime of the asset. In these exceptional cases where renewable energy-based alternatives are proven to be not viable, DFIs should only support small-scale, best-available-technology (BAT) peaking power plants that are designed to promote a progressive integration of larger shares of variable renewable energy into electricity grids. Given that the planning and permitting alone of a gas power plant can take up to a decade, such a burden of proof will generally exclude most proposed plants.

5.2.4 Resilience

DFIs should consider the relevant physical climate risks when evaluating support requests for downstream gas infrastructure. Fossil fuel-based power plants are dependent on the availability of sufficient water reserves. Droughts and changing precipitation levels can affect a plant’s generation feasibility and costs (McDermott and Nilsen, 2014). According to World Resources Institute’s (WRI) analysis, water stress threatens nearly half the world’s thermal power plant capacity (Byers *et al.*, 2018). While there are technological measures that enable gas plants to reduce water needs, they are associated with significant additional costs and lower efficiency (US EIA, 2018). High water temperatures can result in curtailment, reduced plant efficiency, and even plant shutdowns (McCall, Macknick and Daniel, 2016). For gas plants close to coastlines, storms, flooding, and sea level rise can damage generation assets, their gas supply infrastructure, and associated electricity transmission lines. In addition to electricity outages, this poses a risk to the overall stability and resilience of the power system.

Water stress and temperature considerations, as well as the resilience of the plant and its related infrastructure, are risks that should be appropriately priced in and compared to the relatively more resilient capabilities of decentralised renewable electricity systems (Shahid, 2012).

5.2.5 Guidance

As discussed above (see Section 5.1.5), these risk considerations may not necessarily lead to a complete categorical exclusion of electricity generation infrastructure. As an extension to the joint MDB Paris alignment approach, we therefore propose a number of specific questions that can help a DFI in decision-making on whether to support or decline support for a project based on its consistency with the Paris Agreement.

If any of the following questions is answered with a no, the project is likely to undermine the achievement of the Paris Agreement objectives. The proposed criteria set a high bar for the justification of (limited) exceptions, which are likely to be extremely rare if the criteria are robustly applied.



Sector-specific criteria:

- Does the plant conceivably contribute to emissions reductions and the achievement of total electricity sector decarbonisation by 2050?
-

Lock-in risks:

- Is it clear that the plant is only operating in duty modes that enable the integration of higher shares of zero-carbon alternatives (renewable energy, storage, grid interconnections, smart grids, etc.)? This effectively excludes baseload operation and, hence, CCGT plants.
-

Transition risks:

- Is it clear that the expected electricity demand and other required grid services cannot be met with renewables and a combination of storage, grid interconnections to other regions, demand response options/smart grids, and time of use pricing incentive options?
 - Are options for longer-duration storage excluded (primarily geographic considerations for pumped hydropower, CSP options, and others – subject to review of current technological developments)?
 - Is the economic feasibility of the plant justified (positive NPV), despite a constant and rapid reduction in runtime over the lifetime of the asset and accounting for the higher O&M costs associated with flexible duty modes and the resulting increased mechanical fatigue? Is this still the case in a scenario of accelerated and rapid expansion of renewable energy and storage capacity in the medium term?
-

Resilience/physical climate risk:

- For CCGT and gas steam turbines: Is the availability of water guaranteed, considering current and future climate impact modelling of drought? (Not relevant for gas combustion turbines)
 - For CCGT and gas steam turbines: Are ambient temperature likely to be in a range that excludes the possibility of curtailment and significant efficiency losses, considering current and future climate impact modelling? (Not relevant for gas combustion turbines)
 - Is the plant designed to minimise water consumption, e.g. with dry cooling technology? (Not relevant for gas combustion turbines)
 - Have all available measures been taken to ensure the resilience of the plant, associated gas supply, and electricity transmission infrastructure?
 - Is the economic feasibility of the plant justified (positive NPV), considering the additional associated costs of resilience measures (e.g. for dry cooling and ensuring water resource availability and the resilience of the plant itself, as well as the associated supply and transmission infrastructure)?
-

Regardless of the determination regarding whether or not any individual plant meets the criteria to justify an exception to the general gas exclusion, it is imperative that DFIs constantly seek to avoid financing gas plants by scaling up support for alternatives. For example, DFIs should offer financial support to address the perceived investment risks associated with energy efficiency, renewable energy and storage expansion, and grid flexibility/smart grids. At the same time, other policy options to support renewable energy integration and flexibility should be supported, especially electricity market reforms.

Box 8: Gas-fired electricity generation project case study

Project name	Country	Region	Signature date	Budget (USD)
Syrdarya Power Project	Uzbekistan	Central Asia	12/11/2020	EBRD finance: 200 million Total project cost: 1,023 million
Description				
<p>This project aims to decommission 1,170 MW of old and inefficient natural gas-fired power generation and build and operate a new large-capacity combined cycle gas-fired power plant in the Syrdarya region of Uzbekistan. This CCGT investment is supposed to promote private sector participation in the energy market and strengthen the country's power system through more efficient and reliable capacity. Finally, the project seeks to reduce CO₂ emissions via the decommissioning of the inefficient units and the new plant's improved efficiency and reduced carbon intensity.</p>				
Criteria				
Sector-specific criteria				
Q	Does the plant conceivably contribute to emissions reductions and the achievement of total electricity sector decarbonisation by 2050?			
A	<p>⊗ No. The plant has an emission intensity of 338-343 kg CO₂/MWh (NS Energy, 2020) and therefore does not comply with sector-specific emission benchmarks. The project also does not represent a refurbishment of an existing plant focused on reducing leakage or fugitive emissions. Furthermore, the plant is a large CCGT intended for baseload operation, and will discourage greater integration of renewable energy capacity.</p>			
Lock-in risks				
Q	Does the plant enable and help foster the integration of higher shares of variable renewable energy, i.e. by operating in duty modes focused on providing grid services that complement and do not disincentivise zero-carbon alternatives (renewable energy, storage, grid interconnections, smart grids, etc.)?			
A	<p>⊗ No. Designed to provide baseload power, the CCGT plant is unlikely to support the integration of greater shares of variable renewable energy by taking over load following or peaking roles and thus disincentivises zero-carbon alternatives.</p>			
Transition risks				
Q	Is it clear that the expected electricity demand and other required grid services cannot be met with renewables and a combination of storage, grid interconnections to other regions, demand response options/smart grids, and time of use pricing incentive options?			
A	<p>⊙ Unclear. Uzbekistan has an energy potential that is almost four times the country's primary energy consumption needs. The Uzbek government is planning significant investments in scaling up renewable energy, which should represent 25% of the energy production by 2030 (11.2% from hydropower, 8.8% from solar, and 5% from wind) (Sadullaeva, Rakhimov and Usmonov, 2017), and is also investing in large-scale pumped hydropower storage capacity (Power Technology, 2021).</p>			
Q	Have options for longer-duration storage been considered and excluded as unfeasible (primarily geographic considerations for pumped hydropower, CSP options, and others—subject to review of current technological developments)?			
A	<p>⊗ No. The disclosed documentation does not indicate that alternative solutions to provide baseload services from renewable energy plus longer-duration storage are adequately accounted for.</p>			
Q	Is the economic feasibility of the plant justified (positive NPV), despite a constant and rapid reduction in runtime over the lifetime of the asset and accounting for the higher O&M costs associated with flexible duty modes and the resulting increased mechanical fatigue? Is this still the case in a scenario of accelerated and rapid expansion of renewable energy and storage capacity in the medium term?			
A	<p>⊗ Not entirely clear based on the provided information, but highly unlikely. Most CCGT plants, while more efficient than alternative gas plants, must operate in baseload profiles to be profitable. It is not clear that the project would have a positive NPV if plant operations deviated from the standard baseload profile.</p>			

Criteria	
Resilience criteria	
Q	For CCGT and gas steam turbines: Is the availability of water guaranteed, considering current and future climate impact modelling of drought? (Not relevant for gas combustion turbines)
A	 No. The Syrdarya power plant is estimated to consume water at a rate of approximately 1965 m3 per hour (h), sourced from an adjacent canal (NS Energy, 2020). Uzbekistan is a semi-arid country with few internal freshwater resources, inefficient irrigation systems for water-hungry crops like cotton, and a growing population (Egamov, 2019). Increased temperatures, changes in precipitation patterns, and increased drought in the country are likely to impact water availability (USAID, 2018). Potential water conflicts with neighbouring countries such as Tajikistan, on which Uzbekistan is dependent for a large share of the water it consumes (Egamov, 2019), mean that infrastructure projects dependent on water resource availability are likely to face significant physical climate impact risks.
Q	For CCGT and gas steam turbines: Are ambient temperatures likely to be in a range that excludes the possibility of curtailment and significant efficiency losses, considering current and future climate impact modelling? (Not relevant for gas combustion turbines)
A	 No. Average warming in Uzbekistan is predicted to be significant, with summer temperature increases of as much as 5°C (World Bank and Asian Development Bank, 2021). At such levels, the possibility of efficiency loss or even curtailment cannot be excluded.
Q	Is the plant designed to minimise water consumption, <i>e.g.</i> with dry cooling technology? (Not relevant for gas combustion turbines)
A	 Yes. Although the plant is dependent on water cooling, the design of the cooling system is consistent with BAT and does not contribute to increased water intake compared to the previous plant (NS Energy, 2020).
Q	Have all available measures been taken to ensure the resilience of the plant, associated gas supply, and electricity transmission infrastructure?
A	 Unclear. The disclosed information provides no information on measures taken to build adaptive capacity.
Q	Is the economic feasibility of the plant justified (positive NPV), considering the additional associated costs of resilience measures (<i>e.g.</i> for dry cooling and ensuring water resource availability and the resilience of the plant itself, as well as associated supply and transmission infrastructure)?
A	 Not clear.
Investment guidance	
This investment is inconsistent with the Paris Agreement, as it fails to comply with most criteria. Support provided for the decommissioning of the former plant, however, would be Paris-aligned.	

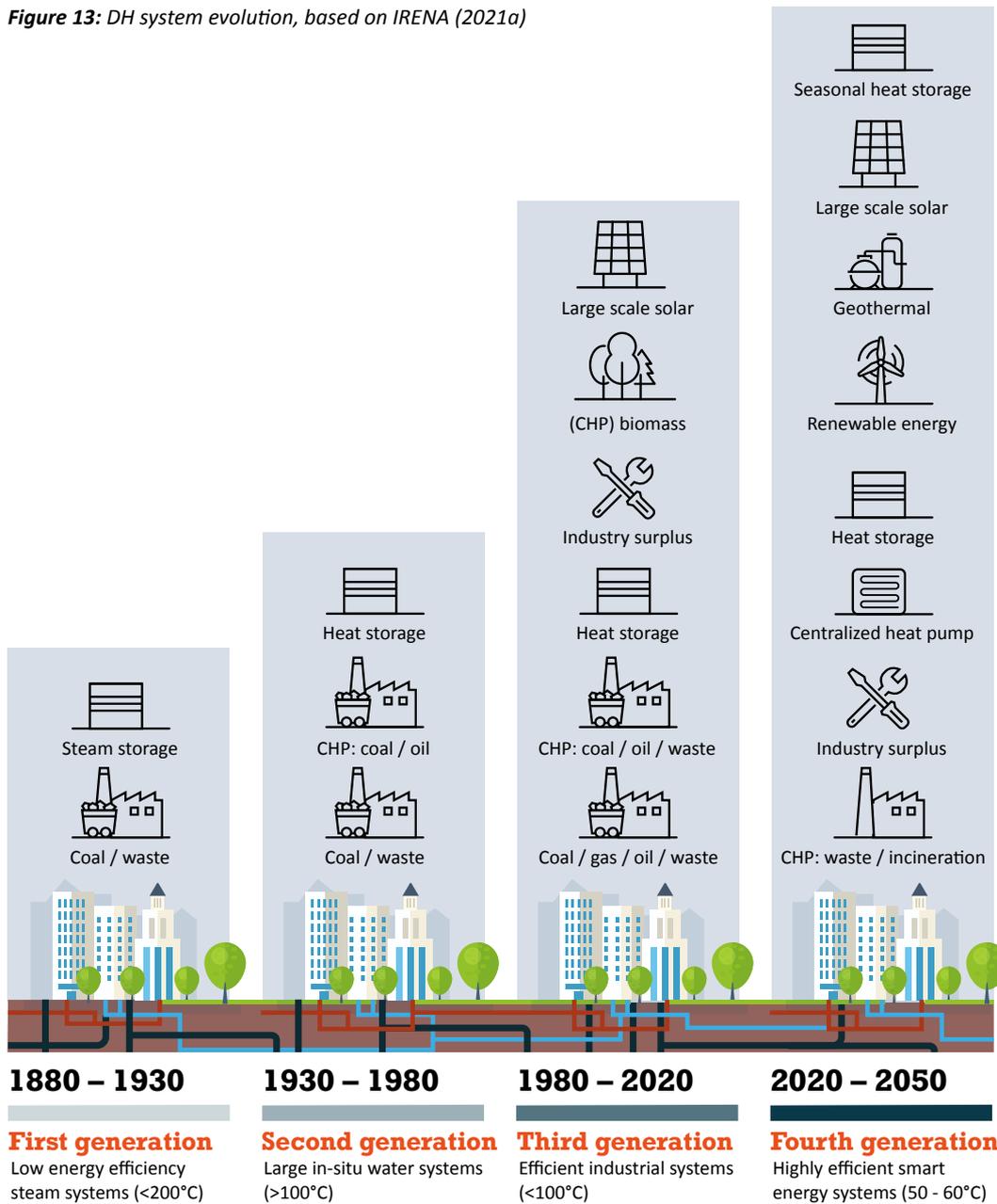
5.3 DISTRICT HEATING/COMBINED HEAT AND POWER

District heating (DH) refers to network systems that pump heated water (historically steam) to consumers for space heating or water heating, cooling, or industrial processes. Although less than 8% of global heat demand was supplied through DH networks in 2018, it is a significant heating technology in China, Russia, and Central Asia, as well as Eastern Europe, Nordic countries, and the Baltics. Currently, most DH systems rely on heat or combined heat and power (CHP) plants that run on fossil fuels such as coal or gas for heat generation. DFIs play an important role in financing DH system modernisation and construction and fund projects often involving conversion from coal to gas or replacement of inefficient gas plants with more modern gas heating plants. Renewable sources of heat, however, must replace fossil fuel-based heat generation to decarbonise the heat sector. Large-scale heat pumps and the efficient use of industry waste and geothermal heat are essential to renewable energy-based DH networks (Gerhardt et al., 2021). The integration of higher shares of renewable low-temperature heat, however, requires efficiency improvements in distribution networks and improved building energy efficiency (IEA, 2020b).

As described by Li and Nord (2018), DH systems have progressed over time and have moved through four generations: first-generation DH systems using steam as a heat carrier; second-generation systems using pressurised hot water as a carrier, with supply temperatures exceeding 100°C; third-generation systems using pressurised water flowing through prefabricated and pre-insulated pipes, but with water temperatures below 100°C; and modern fourth-generation DH systems, which run with lower distribution temperatures and have assembly-oriented parts and more flexible materials. Fourth-generation systems are better able to integrate decentralised heat sources, improved measurement equipment, and advanced information technology – notably to be a demand response asset for decarbonising electricity systems (see Figure 13).



Figure 13: DH system evolution, based on IRENA (2021a)



5.3.1 Inputs from Paris-compatible scenarios: Sector-specific criteria

In the IEA’s Net Zero Scenario (IEA, 2021b), DH (and hydrogen) only account for 7% of energy use in buildings but will continue to play an important role in 2050 in regions with high heating needs and dense urban populations, although energy efficiency and behavioural measures reduce the overall heating demand.

DH grids can contribute to the decarbonisation of heating demand particularly in densely populated areas where they replace decentralised fossil fuel or biomass boilers, with a growing share of heat produced with renewable energy. CHP may play a role in this; however, it is important to ensure that such investments are consistent with an overall path towards decarbonisation. Global benchmarks can help guide consistency with Paris objectives. Although neither the IPCC nor the IEA propose emissions intensity criteria for DH or CHP plants, the EU Technical Expert Group (TEG) has proposed an intensity threshold for CHP or plants with heating/cooling outputs, and the EIB has set criteria for investments on both a plant and heat network level (see

Table 7). On a plant level, the EU TEG and EIB thresholds effectively exclude most heat and power plants that do not include CCS, sustainable biogas, or the mixing of and longer-term conversion to green hydrogen.

The plant-level criteria for heat and power plants are not directly applicable to DH systems involving different heat sources and distribution assets as a whole. For example, the average carbon intensity of DH networks in China, which heavily relies on coal, is around 400 gCO₂/kWh. In comparison, the carbon intensity of Europe’s heat networks, which are already integrating significant shares of renewable energy, is around 150-300 gCO₂/kWh (IEA, 2020c). Similar to the case of gas peaking power plants in electricity generation, however, CHP plants can play a flexibility role, enabling an increased share of renewables in DH systems on a system level (Nuytten *et al.*, 2013). To accelerate the shift to fourth-generation DH systems, the enabling capability of potential CHP investments should be considered, but only where the CHP plant is planned to operate in a flexible role in conjunction with a rapid expansion of renewable heat input, and where it is not feasible to convert a DH system directly into a renewable system.¹⁰

Table 7: Co-generation emission intensity benchmarks

Benchmark	Type	Threshold and description
TEG EU Sustainable Finance Taxonomy Report	Emission intensity for co-generation and gas combustion plants with heating/cooling outputs	100 gCO ₂ e/kWh, declining to 0 gCO ₂ e/kWh by 2050, based on EU emission targets for the energy sector (TEG, 2020).
EIB Energy Lending Policy – for CHP	Emission intensity performance standard	Projects may be eligible if they emit less than 250 gCO ₂ /kWh. Applicable to all technologies, including power generation based on low-carbon energy sources, CCS, with a high proportion of low-carbon fuels, CHP, and decentralised energy sources (EIB, 2019).
EIB Energy Lending Policy – for district heating/cooling networks	Criteria based on overall energy source in the system	Systems using at least 50% renewable energy, 50% waste heat, or 75% co-generated heat, or a 50% combination of energy and heat (EIB, 2019). Furthermore, investments should not lead to an increase in the combustion of coal, peat, oil, or non-organic waste on an annual basis.

¹⁰ The EIB guidance for investments in DH/cooling networks exclude projects that would result in the increased combustion of a number of fuels but does not yet require the investment to be made in the context of an increasing share of renewables in the network.

5.3.2 Lock-in risks

Investments in DH networks and CHP plants carry different risks regarding the extent to which they lock heating systems into emissions-intensive paths. Low-temperature geothermal, solar thermal, and waste heat sources, among others, are low-carbon alternatives that already represent viable renewable energy alternatives to fossil fuel-fired DH networks in many cases (IRENA, 2021a). More efficient options for renewable heat generation are increasingly emerging, but widespread adoption is hampered where markets (*e.g.* unfair competition from subsidised fossil fuel-based technologies) and regulation (*e.g.* building codes) continue to favour fossil fuel-based DH solutions.

For heating networks, continued investment in high-temperature networks (pre-4th generation) risk locking-in system dependence on fossil fuel heating sources. However, new investments to refurbish existing networks or extend networks can make an important contribution to the decarbonisation of heating if they are planned with improved flexible, well-insulated prefabricated parts and are part of a programme focused on shifting towards a fourth-generation DH system with increased alternative and renewable heat input.

Fossil-fuelled CHP plants have a greater risk of driving lock-in to a higher emissions pathway in that when they are run for heat, they are likely to displace renewables in the electricity system, and vice versa. A second revenue source from heat generation runs the risk of prolonging the profitability and lifetime of power plants beyond what it would have been, thus displacing lower-carbon alternatives. Hence, the lock-in risks for CHP are similar to those for electricity generation. More generally, DFIs should also evaluate support for CHP plants against criteria used to assess the Paris alignment of electricity generation.

Decarbonisation modelling for the energy and heat sector forecasts a minimisation of lock-in risk through only smaller, more flexible CHP capacity. For example, the EU Energy Efficiency Scenario (EU-EE) from the EU Energy roadmap foresees only relatively small decentralised new CHP systems—centralised demand is met either with existing CHP capacity or through the conversion of existing power plants (Connolly *et al.*, 2013). Strbac *et al.* (2018) found that small-scale micro-CHP could reduce the capacity of gas-fired plants with a marginal impact on renewable energy deployment. The size of CHP plants can be reduced and their flexibility increased with the addition of thermal energy storage, which can simultaneously complement expanded renewable energy penetration (Nuytten *et al.*, 2013).

It is therefore important that when considering a CHP, in cases where an immediate, direct conversion to renewables is not feasible, lock-in risks are reduced through appropriate planning for an increasing contribution of renewable heat input, minimisation of capacity, and an aggregation of smaller of local units.



5.3.3 Transition risks

The high capital cost of DH and correspondingly long payback period, as well as O&M costs, makes systems vulnerable to transition risks that require careful management. Both inaccurate heat mapping of supply and demand and high projections for future heat demand are significant risks associated with district heating (BNEF, 2020a). Designing centralised CHP systems exposes the heat source plant to transition risk if cheaper heat sources (*e.g.* industrial waste heat or renewables) are later added to the network. To some extent, these transition risks for CHP mirror those in electricity generation (see Section 5.2.3). In many countries, renewable heat sources already represent a cost-competitive alternative with significant social benefits, *e.g.* in terms of reduced pollution (IRENA, 2021a). DFIs supporting the design, construction, and retrofitting of large, high-capacity heat networks in cities with inefficient building stock face transition risks as building renovation and insulation improves. More efficient buildings result in a decline in heat demand and revenue for network operators, and even stranded assets. A rapid expansion of buildings with integrated renewable energy and heat pumps for heat that can be provided at zero marginal cost would make DH uncompetitive, considering the operating (fuel, potential carbon levies, maintenance, etc.) and fixed costs of CHP and DH systems.



5.3.4 Resilience

Climate-related physical impact risks on the gas supply chain make CHP and CHP-dependent DH systems vulnerable to a changing climate, due to their sourcing of both gas and water. In contrast to electricity, heat is unlikely to be in high demand at times when high ambient temperatures result in peaks in power demand.

Heating systems based on renewable decentralised sources of heat can bolster resilience, acting as an additional source of flexibility responding to shifts in renewable electricity and heat supply and demand.

5.3.5 Guidance

As in Sections 5.1 and 5.2, the above mentioned considerations may not categorically automatically lead to a complete exclusion of DH systems and CHP plants. As an extension to the joint MDB Paris alignment approach, we therefore propose a number of questions that can help a DFI in decision-making on whether to support or decline support for a project based on its consistency with the Paris Agreement.

If any of the following questions is answered with a no, the project is likely to undermine the achievement of the Paris Agreement objectives. The proposed criteria set a high bar for the justification of (limited) exceptions, which are likely to be extremely rare if the criteria are robustly applied. The guidance questions are divided into questions on 1) the district heating system network itself; and 2) CHP plants as a heat source.



District heating systems

Sector-specific criteria:

- For new DH networks, extensions, and retrofits, is the investment consistent with BAT in terms of efficiency and flexibility and contributing to a shift towards fourth-generation DH networks?

Lock-in risks:

- Is the system designed to accommodate decentralised heat inputs?
- Is the regulatory regime and network management open to new and renewable heat sources; does it not unduly favour centralised fossil fuel heat or CHP plants?

Transition risks:

- Is it clear that future shifts of centres of heat supply and demand will not render the system unprofitable/result in stranded assets?
- Is it clear that the plant, given its capacity and the size of the system, will remain economically viable even when heating demand decreases in the future, *e.g.* as the result of energetic retrofits and new, stricter building standards (as well as potentially milder future winters)?

Resiliency/physical climate risks:

- Are the heat distribution networks resilient against physical climate impacts?



CHP plants

Sector-specific criteria:

- Does the plant comply with the sector-specific emission intensity benchmark of 100 gCO₂e/kWh, declining to 0 gCO₂e/kWh by 2050?

Lock-in risks:

- For greenfield DH networks: Does the project not discourage the integration of renewable heat inputs?
- Is the regulatory regime and network management open to new and renewable heat sources; does it not unduly favour centralised fossil fuel heat or CHP plants?
- For waste heat capture retrofits: Is it clear that the retrofit does not extend the lifetime of the gas-fired plant?

Transition risks:

- Is it clear that renewable sources cannot currently provide heat for use in DH networks cost-competitively?
- Is the siting of the plant appropriate, considering future centres of renewable heat and heat demand?
- Is the capacity and size of the plant appropriate, considering future demand projections, including energy efficiency improvements?
- Is the economic feasibility of the plant justified (positive NPV), despite a constant and rapid reduction in runtime over the lifetime of the asset, including the higher O&M costs associated with flexible duty modes and the resulting increased mechanical fatigue? Is this still the case in a scenario of accelerated and rapid expansion of renewable energy and storage capacity in the medium term?

Resiliency/physical climate risks:

- Is the availability of water guaranteed, considering current and future climate impact modelling of drought?
- Is the plant designed to minimise water consumption?
- Have all available measures been taken to ensure the resilience of the plant, associated gas supply, and electricity transmission and heat distribution infrastructure?
- Is the economic feasibility of the plant justified (positive NPV), considering the additional associated costs of resilience measures?

5.4 SPACE HEATING, WATER HEATING, AND COOKING AND ASSOCIATED DISTRIBUTION

Gas currently has a number of applications in the building sector, both residential and commercial, which, according to Muttitt *et al.* (2021), account for about 15% of gas consumption in non-OECD countries. Relevant investments in the gas value chain include gas distribution networks, with projects often developed by local utilities, as well as space heating, water heating, and cooking in new buildings and building renovation. Space heating accounts for the largest share of gas consumption in the residential sector on the global level, but in developing countries, cooking accounts for the largest share, due these countries' typically more temperate or tropical climates (Muttitt *et al.*, 2021).

In addition to the CO₂ released from the burning of gas in appliances, the infrastructure and associated appliances in residential and commercial buildings are a source of significant and often underestimated methane emissions, which leak from infrastructure and incomplete combustion. A recent study found that methane leakage in the five largest cities in the U.S. was over two times higher than the official inventory estimates (Plant *et al.*, 2019).

There are readily available alternative technologies to gas for these end uses, but their market penetration is regionally variable (often associated with electricity prices and local zoning). Although electric heat pumps and other renewable heat equipment is gaining market share, it still only represented approximately 10% of the global market in 2019 (IEA, 2020c). However, it is notable that in consideration of the emissions associated with gas distribution networks and household appliances, a growing number of jurisdictions are already starting to take measures to prohibit gas use in new buildings (McKenna, 2019; DiChristopher, 2021; Gough, 2021), or going further to set dates to completely phase out gas. Amsterdam, for example, plans to eliminate gas use by 2040 (Amsterdam, 2021); similarly, Vancouver, British Columbia aims to phase out use by 2050 (Slattery, 2016). California recently revised its building code to make electric only the default option for new construction (St. John,

2021). Compared to gas, building electrification is further associated with other important health and environmental benefits, such as improved indoor air quality (Seals and Krasner, 2020). For new residential buildings, the cost savings from full electrification compared to gas connections and gas appliances can be significant (McKenna, Shah and Louis-Prescott, 2020), especially if the building produces its own electricity. Avoiding building additional gas distribution networks and buildings dependent on gas-fired space heating, water heating, and cooking could enable other cities and states to leapfrog to the vanguard that Amsterdam and Vancouver represent.

5.4.1 Inputs from Paris-compatible scenarios: Sector-specific criteria

A number of relevant Paris-compatible benchmarks have been developed for the building sector, with important implications for gas's role in heating and cooking in buildings. Notably, in the IEA's Net Zero Scenario, gas use is markedly reduced by 2030 and completely phased out by 2050 in building end uses, in a complete shift away from fossil fuels (IEA, 2021b). According to the IEA, energy efficiency and electrification are the main two measures to drive decarbonisation of the buildings sector; electricity will progressively replace fossil fuels for space heating, water heating, and cooking (IEA, 2021b).

Climate Action Tracker analysis found that in 1.5°C-compatible scenarios, new buildings generate as much renewable energy onsite as they consume on a net annual basis by 2020 in Organisation for Economic Co-operation and Development (OECD) countries and 2025 in non-OECD countries. This needs to be combined with deep renovation rates of 5% and 3% per year, respectively (Climate Action Tracker, 2016). The heating sector is not currently on track to meet either these benchmarks or those in the IEA's Sustainable Development and Net Zero Scenarios (IEA, 2020c).

Table 8: Sector-specific benchmarks for the building sector

Benchmark	Type	Threshold	Description
<i>Climate Action Tracker Paris Agreement 1.5°C-Compatible Benchmarks</i>	Percentage reduction in emission intensity for residential buildings from 2015 levels	90% by 2040; 95-100% by 2050	Paris-agreement compatible benchmarks for 2040 and 2050 emission intensity reductions for residential buildings (Climate Action Tracker, 2020).
<i>IEA Net Zero Scenario</i>	Starting year for fossil fuel boiler phase out	Ban on fossil fuel boilers by 2025	The IEA expects that to achieve net-zero emissions by 2050, a ban on fossil fuel boilers must come into effect by 2025 in order for electricity to reach a market share of 55% of building heating demand (primarily through heatpumps) by 2050 (IEA, 2021b). Other significant shares come from solar thermal, and district heating.
<i>IEA Sustainable Development Scenario (SDS)</i>	Market share in 2030	Share of clean heating technologies (including heat pumps) must represent 50% of sales by 2030.	Reaching a market share of clean heating technologies of 50% by 2030 represents a doubling from 2019 levels. Note: According to Oil Change International (Trout, 2019), the SDS would give a 66% chance of limiting warming to 1.8°C but may lead to an overshooting of 2°C, suggesting its weakness in providing a guide for Paris alignment.

DFIs can play an important role in bringing this about by supporting countries in developing, implementing, and enforcing building codes that mandate energy efficiency and electrification and exclude gas for new buildings; generally ending financial support for gas (and other fossil fuel) use in buildings; and mobilising finance and initiatives to promote gas phase-out through electrification and energy-efficient renovation of existing buildings.

5.4.2 Lock-in risks

The installation of gas distribution infrastructure and financial support for buildings with gas connections and gas for space heating, water heating, and cooking implies high lock-in risks. Gas appliances have an average lifespan of approximately 10-20 years (see Table 9), although they often last longer, depending on the appliance and application. The lifespan of these appliances indicates that new investments in these technologies would ensure continued CO₂ emissions from gas combustion and methane leakage. Furthermore, such investments in gas end uses would represent an important missed opportunity to contribute to the electrification of the building sector—a key measure to achieve the Paris objectives.

Although there are various proposals and pilot projects to mix hydrogen into gas distribution networks (or convert networks entirely), there are a number of efficiency, technical, and cost challenges associated with this, which implies a higher lock-in risk for investments made now. Renewable electricity-based electrofuels (e-fuels) such as hydrogen or other synthetic gases have approximately 10-35% efficiency—this implies renewable electricity requirements are roughly 2-14 times that of direct electrification for the same end use (Ueckerdt *et al.*, 2021). For gas distribution networks with metal pipes, hydrogen

reacts with the metal, making it brittle (Hafsi, Mishra and Elaoud, 2018), which means that the gas distribution network would need retrofitting, *e.g.* of high hydrogen penetration. Although polyethylene pipes (which are now more commonly used to transport gas than steel and iron pipes) are not vulnerable to embrittlement, they are more porous to hydrogen than gas, making them prone to leakage. This, combined with hydrogen leakage from the connections between polyethylene pipes, means that pipes that are tight enough for natural gas may pose a safety hazard when converted to hydrogen (Dodds and McDowall, 2013). The theoretical possibility of future conversion to alternative gases therefore often does not sufficiently address lock-in risks associated with investments in gas end uses in new buildings with electricity access. The cost of the large amount of additional electricity required, additional electrolyser capacity, safety issues, and technical measures required to retrofit gas infrastructure are not yet completely clear, but they present significant disadvantages compared with direct electrification. This uncertainty implies that additional gas infrastructure for space heating, water heating, and cooking in the building sector presents significant lock-in risks in the short to medium term and should be avoided wherever electricity is available.

Table 9: Lifespan of residential and commercial gas end use appliances, based on Seiders *et al.* (2007)

Benchmark	Type
Gas clothes dryer	13
Gas range/stove top	15
Gas water heater	10
Gas boiler	21
Gas warm air heating furnace	18



Box 9: Clean cooking

Approximately 3 billion people worldwide rely on cooking methods that involve burning biomass in rudimentary cookstoves or on open fires. Incomplete combustion of solid biomass fuels results in short-lived climate pollutants, such as black carbon (Clean Cooking Alliance, 2021). Indoor air pollution in the form of fine particulate matter is estimated to cause 4 million premature deaths annually (WHO, 2018). Women carry a disproportionate share of this health burden (SE4ALL, 2020). Additionally, fuelwood harvesting drives deforestation and forest degradation (Specht *et al.*, 2015).

Alternative solutions that meet internationally defined clean cooking standards include electric cooking, ethanol cooking, improved biomass stoves, and LPG stoves (Alderman, 2019). Considering the expansion and cost advantages of renewable energy in electricity generation, electrification is the cleanest option; however, this requires access to reliable sources of electricity. It should be a priority for development finance to mobilise support for integrated approaches to energy access provision that simultaneously target electricity access and the promotion of electric cookstoves. Electricity

supply technologies, including decentralised solutions such as solar home systems and mini-grids, can provide the required peak capacity (>2000 W) to run efficient electric cooking solutions (World Bank, 2015). A major advantage of electric cooking is that it is often already the cheapest solution (Coulter and Jacobs, 2019), a fact increasingly recognised by governments, including in Ecuador and Kenya (Muttitt *et al.*, 2021).

The promotion of electric (and, to a lesser extent, biogas and ethanol) stoves where fuels can be sourced sustainably should be the default approach to advancing access to clean cooking solutions. In contrast, the large-scale adoption of LPG stoves in developing countries results in the lock-in of emission-intensive technology and distribution infrastructure, delays the deployment of cleaner alternatives, and exposes low-income households to fuel price volatility risks. Locally sourced and produced biomethane made from sustainable feedstock sources represents a superior alternative, subject to water constraints. Support for LPG should be limited to exceptional cases where other options are not feasible.



5.4.3 Transition risks

In comparison to other gas end uses, transition risks are currently more limited for gas-fuelled space heating, water heating, and cooking because of the split incentives between property developers/construction companies, property owners, and building occupants. Decisions to buy or rent a house, an apartment, or a commercial building are often influenced more by location, property prices, and rent than uncertainties around potential future gas, hydrogen, or other synthetic fuel prices compared to the price of electricity. This, however, may change in the future. As the number of jurisdictions implementing carbon pricing grows, the use of gas is likely to become more expensive, representing a disincentive for potential property renters or buyers. Similarly, a growing number of jurisdictions are moving to phase out gas in buildings, not only for new buildings, but also for existing ones. Already, the UK and New York City have started to impose penalties/restrictions on renting out buildings that do not meet certain energy efficiency standards (Energy Saving Trust, 2019; Kimmel, 2019).

Of the different clean heating/cooling alternatives available, heat pumps have distinct technological and economic advantages. Electric heat pumps could provide 90% of global space and water heating needs with lower lifecycle carbon footprints than gas-fired condensing boilers (IEA, 2020b). Heat pumps are highly efficient in the use of energy (electricity) to produce heat by transferring energy from ambient heat (air-to-air, ground-to-air, ground-to-

water), resulting in efficiencies 6-14 times higher than that of hydrogen or e-fuels (Ueckerdt *et al.*, 2021). Heat pump technology has advanced significantly, with air source heat pumps, for example, now capable of efficiently providing clean heat in regions with temperatures well below -23°C (-10 degrees Fahrenheit (°F)) (Gartman and Shah, 2020). As such, direct electrification is significantly cheaper than using e-fuels for space and water heating. For real estate owners and renters, this means significant long-term cost disadvantages for current gas investments in new residential and commercial applications. At the same time, the deployment of residential heat pumps will triple by 2030 (IEA, 2020b). High upfront investment and lack of policy support remain major barriers.

Heat pumps for both space and water heating have the potential to become significantly more attractive for utilities, considering that they can also provide grid services via demand response. Given that small temperature changes are generally perceptible in terms of human comfort, heat pumps can help reduce peak electricity demand or otherwise ramp up when there is a surplus of renewable electricity in the grid. This has been demonstrated by several pilots in Ireland (Merchant, 2021) and the state of Connecticut in the U.S. (St. John, 2019). The flexible characteristics of heat pump alternatives mean that buildings that are not equipped with smart heating systems are liable to become less attractive for potential occupants or would require costly retrofits before the end of the heating equipment's life.



5.4.4 Resilience

DFIs should consider relevant physical climate risks when evaluating support requests for residential and commercial space heating, water heating, and cooking. Gas transport and distribution networks are prone to damage caused by flooding, excessive precipitation levels, sea level rise, extreme temperatures (heat and cold), and indirect physical factors (e.g. soil erosion and landslides). Decentralised electricity provision is much more resilient to climate impacts, as demonstrated by growing demand for residential PV plus behind-the-meter storage after extreme weather events in California and Texas (Mulkern, 2020; Chapa, 2021).

Gas leakage from distribution networks can become a serious safety issue. When taking investment and support decisions, DFIs should ensure they account for physical climate risks and the costs and consequences of transmission asset damage.

5.4.5 Guidance

For residential and commercial space heating, water heating, and cooking, gas connections for new buildings and refurbishments are not aligned with the Paris agreement, considering sector-specific criteria, lock-in risks, transition risks, and physical climate risks. The technological maturity of alternatives based on electrification means that Paris alignment frameworks should completely shift towards alternatives based on electrification via heat pumps for space heating and water heating, DH in certain cases of heavy population density and availability of renewable heat sources, and electric cooking solutions such as induction.

Exceptions may include measures to reduce leakage/fugitive emissions in residential gas distribution networks that do not extend the lifetime of that infrastructure. In limited instances where electric and biogas/bioethanol alternatives are proven unfeasible, LPG stoves may be justified.



5.5 TRANSPORT

Overall, gas plays a negligible role as a fuel in the transport sector. On a global level, gas is used for only slightly over 2% of road transport and less than 0.2% for shipping (IEA, 2020e). This is similar in both OECD and non-OECD countries.

There are various proposals for increased use of gas, generally in the form of CNG for road transport and LNG for shipping. Although gas may have advantages in terms of air pollution in the transport sector compared to diesel and heavy fuel oil, it offers little to no advantage in terms of GHG emissions (Englert, Losos, Raucci and Smith, 2021b). Worryingly, the preference for LNG as a fuel for shipping is increasing despite its lack of climate benefits, considering methane leakage (Pavlenko *et al.*, 2020). This has led to a sharp increase in methane emissions from the shipping sector, which rose by 150% in 2012-2018 (IMO-MEPC, 2020). This development will eventually lead to a shift in the emission profile of shipping's climate impact, which has historically been dominated by CO₂ and black carbon.



5.5.1 Inputs from Paris-compatible scenarios: Sector-specific criteria

The IEA's Net Zero Scenario foresees a steep reduction in transport emissions, from 7 gigatonnes (Gt) CO₂ in 2020 (8.5 Gt in 2019, before the COVID-19 pandemic), to around 5.5 GtCO₂ in 2030, to 0.7 GtCO₂ in 2050 (IEA, 2021b). Emissions are almost eliminated for two-/three-wheelers by 2040 and cars, vans, and trains by the late 2040's. Modelling for Paris-compatible scenarios projects significant roles for modal shifts, electrification, electric and hydrogen fuel cells, and hydrogen-based fuels, including hydrogen and ammonia, but no significant role for gas in any mode of transport (IEA, 2021b).

Although the advancement of electric vehicle technology suggests that gas will not play a significant role in the decarbonisation of the road transport sector, there is somewhat more debate on LNG's role in shipping, considering current efforts to reduce air pollution from shipping, which generally uses heavy fuel oil, but has recently made rules to reduce sulphur oxide emissions, a key air pollution driver (IMO, 2020). Limitations in the sustainable scalability of biomethane and synthetic methane suggest that these alternatives are incompatible with overall emission targets (Englert, Losos, Raucci and Smith, 2021a). Considering the significant challenges of LNG use in shipping, including the build out of the bunkering infrastructure and bunkering of the fuel on ships, IEA categorically excludes it from shipping in its Beyond 2°C Scenario (B2DS) (IEA, 2017).

5.5.2 Lock-in risks

Lock-in risks are very high for road transport and shipping, both in terms of the vehicles themselves and the fuel infrastructure.

Road transport

The average age of the vehicle fleet in the EU is around eleven years for cars, vans, and buses and thirteen years for trucks (ACEA, 2021). In developing countries, these average lifetimes are often significantly higher, given the exports of used vehicles from developed to developing countries (UNEP, 2020b). This export market undermines a direct shift to electric mobility and ensures continued general air and GHG pollution in developing countries (UNEP, 2020b). As this is currently the case with gasoline and diesel motor vehicles, this would also be the case with any investments in CNG motor vehicles. Furthermore, the high investment required to build up CNG infrastructure would contribute further to such a high-emission path lock-in (Muttitt *et al.*, 2021).

Maritime transport

The average age of all ships in the global merchant fleet is over twenty years old, and cargo ships are older—on average, about 26 years old (Statista, 2021). Since retrofitting is costly not only in terms of direct costs, but also in terms of opportunity costs while a ship is not in use, ships are particularly vulnerable to lock-in in terms of their propulsion technology and associated fuel types. Because of the different physical properties of various LNG and other fuels, LNG storage tanks can only be used to store LNG, making them especially vulnerable to fossil fuel lock-in (Pavlenko *et al.*, 2020). The support and expansion of LNG as a shipping fuel is problematic, because in order to reach International Maritime Organisation's (IMO) and Paris climate reduction targets, ships would have to undergo two shifts: 1) a shift from current heavy fuel oil to LNG; and 2) another one from LNG to zero-carbon fuels by 2050 (Englert, Losos, Raucci and Smith, 2021b). Making two shifts in such a short time period is unlikely—leading to a probable lock-in and reducing the uptake of superior climate-friendly technologies such as wind-assisted propulsion, hydrogen, ammonia, batteries, and fuel cells (Pavlenko *et al.*, 2020). Notably, Maersk, one of the world's largest container shipping companies has ruled out has ruled out using LNG as a transitional fuel (Kutin, 2021).

5.5.3 Transition risks

Investments in gas fuelling infrastructure, vehicles, and ships are subject to significant transition risks, given the cost-competitiveness of alternatives, as well as regulatory action to address emissions.

Road transport

While electric vehicles may currently be more expensive than CNG in terms of upfront costs in some jurisdictions, they are considered technically superior, and their costs are falling rapidly. This is largely associated with the cost of Li-ion battery packs, which are expected to drop to 93 USD per kWh by 2023, at which point an electric vehicle will be cheaper to manufacture than an internal combustion vehicle (Stringer and Park, 2020). CNG infrastructure faces similar transition risks to other fossil fuels in the wake of wider adoption of electric vehicles.

For long-haul trucks (up to 600 km range), research by the U.S. Department of Energy Berkeley National Laboratory finds that despite the higher upfront costs of an electric truck in 2021, they have an overall cost of ownership advantage of 13% per mile, amounting to USD 200,000 over the truck's lifetime (Phadke *et al.*, 2021). This cost advantage is expected to grow rapidly with a reduction in battery costs, with a 50% savings by 2030 (Phadke *et al.*, 2021). A number of companies are already developing electric buses and long range and delivery trucks, including Daimler (2021), Rivian (Amazon, 2021), Arrival (Boudette, 2021), and Scania (Morris, 2021). With declining market demand and higher costs, investments in CNG are likely to leave infrastructure and vehicle owners at a competitive disadvantage and with stranded assets.

Maritime transport

Although, in theory, liquefied biomethane and liquefied synthetic methane could be used as a drop-in fuel to gradually replace LNG in ships, these fuels are unlikely to be economically competitive, considering the limited availability of sustainable feed stocks for biomethane and the multiple energy-intensive steps in their production, which undermine efficiency and increase costs, particularly for synthetic methane (Englert, Losos, Raucci and Smith, 2021a). This cost disadvantage is especially stark in comparison with other fuels such as hydrogen or ammonia (IRENA, 2020). Lower emissions from shipping assets will become increasingly important as carbon pricing comes into effect, *e.g.* in the case of the inclusion of international shipping in the EU Emissions Trading System (ETS) (European Parliament, 2020). Although there are clear advantages of other fuels such as hydrogen or ammonia in terms of their climate impact and lock-in, transition, and physical climate risks over LNG as a fuel for maritime vessels, they are not yet widely commercially available for long distances. Dual-fuel ships that can run on conventional fuels such as marine gas oil and later be converted to ammonia are the best currently readily available technology to avoid fossil fuel lock-in and manage transition risks. This dual-fuel engine strategy has recently been adopted by Maersk, one of the world's largest container shipping companies, which recently ordered eight new ships that can run on either marine fuel or (synthetic) methanol (Kutin, 2021; Wittels, 2021).

For shorter distances, including short sea shipping and inland waterways, both fully electric and hybrid vessels are already in service, primarily in Europe (Fahnestock and Bingham, 2021), as well as on a smaller scale in other countries such as Thailand (Danfoss, 2020). With scaled production and reductions in the cost of electric battery technology, costs are expected to fall accordingly.

5.5.4 Resilience

Road transport

For road transport, as previously noted, long supply chains make CNG infrastructure and refuelling options more vulnerable to disruptions caused by climate change-aggravated extreme weather events. This is particularly the case in comparison to systems based on decentralised renewable energy and electric mobility, as noted by U.S. Energy Secretary Granholm (White House, 2021).

Maritime transport

Regarding shipping, the fact that gas must be cooled to -160°C in order to liquefy it means that higher ambient temperatures imply higher liquefaction and storage costs (Smith, 2016). By comparison, ammonia is liquid at -33°C or 8.5-10 bar pressure (Register, 2020) and is therefore less sensitive to the challenges encountered with the high ambient temperatures associated with climate change. Methanol is similarly a liquid at temperatures between -93.9 °C (-137 °F) and 64.96 °C (148.93 °F) (Brittanica, 2019).

5.5.5 Guidance

Road transport

Given the clear technological advantages of electric mobility and the lock-in, transition, and physical climate risks of CNG promotion as a transport fuel, as well as the lack of existing CNG fuelling infrastructure, investments in CNG-based road transport are not Paris-aligned and should not be supported.

Maritime transport

LNG for shipping is not Paris-aligned and should be excluded as an investment. Instead, for long distance shipping vessels, DFIs can best manage lock-in and transition risks in their maritime sector finance by ensuring maximum efficiency measures¹¹ and supporting exclusively dual-fuel engines that can run on conventional fuels and be converted to run on ammonia or methanol in the future.

For short sea shipping and inland waterways, options for full electrification or hybrid solutions without LNG are more mature. Therefore, LNG for these categories of ships should be excluded.

¹¹ For example, optimised engine and hull design, wind-assisted propulsion (*e.g.* rotor sails), hull air lubrication, best available propeller technology, shore power connections, battery backup for at-berth operations when shore power is not available, and hydrogen fuel cells for zero-emissions operations in the port.

6. CONCLUSIONS, LIMITATIONS, AND FUTURE RESEARCH

Considering the climate impact of gas, the limited carbon budget, lock-in risks, transition risks, and resilience considerations, most gas-related investments across the gas value chain are not Paris-aligned. There is, however, a need for further research in a number of areas on how DFIs can align their lending practices to best fulfil their development mandates and commitments to Paris alignment.

We have proposed inputs for the evaluation of gas-related project proposals based on the presented considerations announced in the MDBs' mitigation and adaptation blocks. In doing so, we have highlighted significant mitigation and climate resilience risks.

Although several MDBs have already excluded support for upstream projects, this is not universal among MDBs or DFIs. Importantly, this often does not include LNG export facilities, which are closely related to upstream extraction and production, gathering, and processing. Development finance support for these projects is not Paris-aligned, considering the existing excess of operational and already approved projects and shrinking global carbon budget, as well as the associated transition risks. Furthermore, the development of gas production and export infrastructure exacerbates fossil fuel dependence, undermining other economic sectors in the affected country.

More research is needed on how DFIs can support just and inclusive transitions within the SDG context in developing countries with fossil fuel reserves. This is essential in helping countries avoid falling victim to the resource curse and stranded assets. DFIs have an important potential role to play in broad macro-economic support, industry restructuring, and inclusive and socially just supportive policies.

Despite arguments for repurposing with low-carbon gases, the justification for midstream pipelines is weak. Significant lock-in and transition risks also result from the questionable feasibility of repurposing and low comparative likelihood that centres of supply and demand for low-carbon gases will correspond to current gas trade. However, for existing pipelines, DFIs may choose to support measures that reduce fugitive emissions, most of which can be done on at least a cost-neutral basis.

Mature and cost-competitive clean alternatives shrink or eliminate the role for gas in downstream uses in various sectors—development finance should rather focus on scaling up these clean alternatives. Inputs from Paris-compatible modelling and the significant lock-in, transition, and physical climate risks emphasise that support to gas-fired electricity generation and DH/CHP plants should be limited to an absolute minimum in the context of a rapid buildout of renewable alternatives, storage, and flexible, dynamic electricity and heat grids. In exceptional cases, however, support for new gas infrastructure can be designed to enable the integration of higher shares of renewable energy.

Technologically mature and cost-competitive alternatives are commercially available for space and water heating, as well as cooking. This implies that DFIs should concentrate their efforts on scaling up these alternatives and avoiding any further investment in gas connections or appliances in residential and commercial buildings. LPG may be justified only in cases where there is no stable electricity supply or options for sustainable biogas alternatives.

Given the clear technological advantages of electric mobility, the lock-in, transition, and physical climate risks of CNG promotion as a transport fuel, and the lack of existing CNG fuelling infrastructure, investments in CNG-based road transport are not Paris-aligned and should not be supported. For shipping, dual-fuel engines, for example, that can run on MGO and later be converted to use ammonia for fuel are a commercially available viable and superior alternative.

Downstream, future research is needed to explore how DFIs can support emerging and developing countries in decarbonising their hard-to-abate sectors such as industry. Some industry processes face barriers to electrification or need alternative feedstocks, *e.g.* for fertilisers. In such cases, further research is required on options to upscale and take advantage of opportunities to become suppliers of low-carbon gases such as hydrogen, especially considering the enormous renewable energy potential in developing countries.

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