CLIMATE CHANGE
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Final report

Potentials for Offset Approaches in Selected Sectors post 2020

by:

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Abstract: Potentials for Offset Approaches in Selected Sectors post 2020

This report develops an evaluation framework that policymakers can use to identify whether offsets can add value and uphold environmental integrity of a compliance scheme. It uses a scoring framework on factors to: (1) identify which sectors have hard-to-abate emissions that can justify demanding offsets as cost-containment measures for ambitious climate policies; and (2) identify mitigation activities that are otherwise inaccessible, fosters sustainable development, and the extent to which it enables transformative sectoral action to be eligible to supply offsets. This evaluation framework identifies the optimal conditions that make factors successful in either having sectors demand offsets, or specific mitigation activities supply offsets. Sectoral emissions that are hard-to-abate are those that are technically unavoidable due to a lack and maturity of technologies, and therefore should be allowed to have cost-containment measures – such as offsets – to avoid adverse economic ramifications such as carbon leakage. Mitigation activities that can supply offsets are those that are currently inaccessible to local actor's due to lack of access to technology, finance or capabilities. Allowing these mitigation activities to be eligible to supply offsets allows to pilot such activities and realize mitigation outcomes outside the original scope of the compliance scheme. This report has chosen selected sectors and mitigation activities to illustrate how this framework can be applied at the global level. It recognizes that country-specific factors can change the assessment of whether the offset approach will add value and uphold environmental integrity to proposed compliance schemes of a country. The report further proposes practical steps policymakers can do to undertake an evaluation at the national level.

Kurzbeschreibung: Potentiale für Offset-Ansätze in ausgewählten Sektoren in der Zeit nach 2020

Dieser Bericht entwickelt einen Bewertungsrahmen, den politische Entscheidungsträger nutzen können, um festzustellen, ob Offsets unter Sicherstellung der ökologischen Integrität des Compliance-Systems einen Mehrwert schaffen können. Es nutzt einen Bewertungsrahmen für diese Faktoren, um: (1) Sektoren zu identifizieren, welche aufgrund schwer zu reduzierenden Emissionen Offsets als Kostendämpfungsmaßnahme für ambitionierte Klimaziele rechtfertigen; und (2) zu identifizieren, welche Emissionsreduzierungen anderweitig unerreichbar wären, eine nachhaltige Entwicklung fördern, und inwieweit sie transformative sektorale Maßnahmen ermöglichen, die für die Bereitstellung von Offsets in Frage kommen. Dieser Bewertungsrahmen identifiziert die optimalen Bedingungen, unter denen Sektoren erfolgreich Offsets nachfragen oder bestimmte Minderungsaktivitäten Offsets anbieten können. Schwer vermeidbare sektorale Emissionen sind solche, die aufgrund fehlender und unausgereifter Technologien technisch nicht vermeidbar sind und daher Kosteneindämmungsmaßnahmen - wie zum Beispiel Offsets - zulassen sollten, um negative wirtschaftliche Auswirkungen wie Carbon Leakage zu vermeiden. Minderungsaktivitäten, die Offsets anbieten können, sind solche, die derzeit für lokale Akteure*innen unzugänglich sind, weil sie keinen Zugang zu Technologie, Finanzen oder Fähigkeiten haben. Die Zulassung dieser Minderungsaktivitäten zur Bereitstellung von Offsets ermöglicht es, solche Aktivitäten zu erproben und Minderungsergebnisse außerhalb des ursprünglichen Geltungsbereichs des Compliance-Instruments zu erzielen. Dieser Bericht untersucht ausgewählte Sektoren und Minderungsaktivitäten, um zu veranschaulichen, wie dieser Bewertungsrahmen auf globaler Ebene angewendet werden kann. Er erkennt an, dass länderspezifische Faktoren die Beurteilung, ob der Offset-Ansatz einen Mehrwert bietet und die Umweltintegrität eines Compliance-Systems aufrechterhält, verändern können. Der Bericht schlägt darüber hinaus praktische Schritte vor, die politische Entscheidungsträger*innen unternehmen können, um eine Bewertung auf nationaler Ebene vorzunehmen.

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List of abbreviations

BMU	Federal Ministry for Environment, Nature Conservation and Nuclear Safety
CCS	Carbon capture and storage
CCUS	Carbon capture, utilisation and storage
CHP	Combined heat and power
CO_2	Carbon dioxide
CO-BF-BOF	Coke oven-blast furnace-basic oxygen furnace
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EAF	Electric arc furnaces
EITE	Emissions-intensive, trade-exposed
EU	European Union
EV	Electric vehicle
GHG	Greenhouse gas
IAMs	Integrated assessment models
IEA	International Energy Agency
LDCs	Least Developed Countries
MRV	Monitoring, reporting and verification
NCSs	Natural climate solutions
NDC	Nationally Determined Contribution
RGGI	Regional Greenhouse Gas Initiative
SDG	Sustainable Development Goal
TRL	Technology Readiness Level
UBA	German Environment Agency
UK	United Kingdom
UN	United Nations
US	United States
WASH	Water, sanitation and hygiene

Summary

Policymakers considering the use of offsets within compliance-systems are confronted with the challenge of having to determine which sectors and activities should be incorporated into the demand and the supply side of the envisaged offset approach. In order to explore the factors and indicators that can assist policymakers in this process, two perspectives should be taken into consideration:

A **demand-side perspective** considers which sectors (or facilities within a sector) are identified as having hard-to-abate emissions and could therefore be eligible for using offsets as cost-containment measures to avoid adverse economic effects.

A **supply-side perspective** considers which technologies could benefit from carbon financing in order to realize emission reductions that are otherwise inaccessible due to technological, financial or other barriers.

The objective of this report is to provide evaluation frameworks that can guide policymakers on how to identify: (1) **'hard-to-abate'** emissions (which identifies sectors/facilities that could be eligible to demand offsets) versus those that are easy to abate; and(2) mitigation options that are **inaccessible** (which identifies those mitigation activities that could supply offsets) versus those that are accessible (and therefore do not need the carbon finance mechanism in order to be implemented). These evaluation frameworks provide categories of success factors that indicate the probability that offsets will add-value and uphold environmental integrity of the compliance scheme. This report then applies these evaluation frameworks to selected sectors and mitigation options to help policymakers compare which are most likely to be suitable for offsets, either from a demand or supply perspective. This report is part of the research project "Analysis of the advantages and disadvantages of offset approaches in selected sectors – FKZ 3719 42 507 0", the final results of which were recorded in three separate reports. It builds on the findings of the case studies described in the report *Offset approaches in existing compliance mechanisms—Adding value and upholding environmental integrity?* (Carvalho et al. 2021) and on the conceptual approach developed in the report *Suitability and Success Factors of Offsets post 2020* (Kreibich et al. 2021).

It should be noted that these evaluation frameworks were developed for an assessment at global level. Taking into account the in-country factors (such as policy, current sectoral/technological landscape, and actor's abatement capacity) can lead to different results with regards to the suitability of offsets for each country.

Sectors that could qualify for demanding offsets

Sectoral emissions that are hard-to-abate are those that are technically unavoidable due to a lack and maturity of technologies. This implies the costs of abating would be prohibitively high and lead to adverse economic consequences, such as carbon leakage. Carbon leakage refers to when the imposition of carbon costs on industrial emitters provides a comparative advantage to firms that do not face the same carbon price, thereby incentivizing domestic production to relocate to jurisdictions without a carbon price. Furthermore, domestic actors may lack the financial resources or technological know-how to innovate or implement best-in class mitigation options. Due to carbon leakage risk, policymakers currently provide either full or partial exemptions from stringent compliance schemes (via climate targets or carbon pricing) for hard-to-abate sectors. However, in order to incentivize compliance actors in these sectors to invest in long-term strategies for decarbonizing their operations, policy signals need to be put in place to demonstrate such cost-containment measures are just interim measures.

Table 1 provides an evaluation framework that policymakers can use to determine whether a sector (or specific facilities) should be allowed to use offsets to meet more ambitious compliance requirements, based on identifying the optimal conditions of specific indicators.

Table 1: Summary of the optimal level for factors to be successful to qualify as a sector in demanding offsets

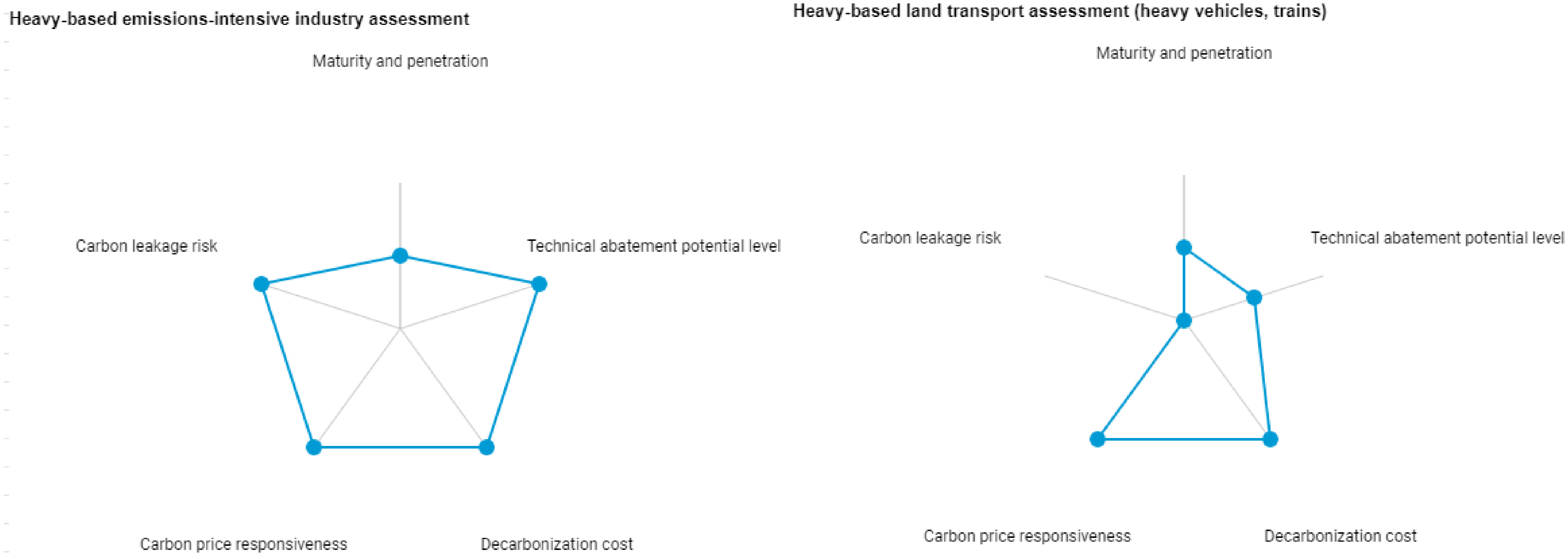
Category	Success factor	Optimal level for offsets demand
Policy-related	Nationally Determined Contribution (NDC) coverage National climate policy coverage Carbon pricing coverage	High policy ambition: NDC targets, national policies and carbon pricing would cover sectoral emissions that are hard-to-abate in terms of scope and ambition, implying the need for cost-containment measures to meet higher ambition.
Technical	Maturity of low-carbon technologies and penetration in the market	Low maturity: Mitigation options do not have commercial maturity to be readily deployed to reduce sectoral emissions.
	Volume of mitigation	Low volume of mitigation: The volume of emission reductions that could be achieved by identified mitigation options for the sector would not be significant enough to meet targets.
Economic	Decarbonization cost	High costs: The costs of mitigation options are significant due to large upfront capital costs and operational costs.
	Carbon price responsiveness	Low carbon price responsiveness: Actors in sector are very unresponsive to compliance schemes/carbon prices due to the costs of being higher than the compliance.
	Carbon leakage risk	High carbon leakage risk: Facilities are at risk of carbon leakage due to being highly emissions-intensive and trade exposed.[1]
Actor's abatement capacity	Financial resources	Low financial resources: Compliance actors do not have the financial resources to deploy mitigation options, and would thus pay high compliance costs on emissions that are technically unavoidable.
	Technical know how	Low technical know-how: Low access to technical knowledge required to deploy mitigation options (likely due to immaturity of technology as well).

Source: South Pole

[1]Policymakers could use quantification assessments that are developed by the European Union to determine whether facilities are at risk of carbon price leakage due to suggested carbon price, which can prevent political bias caused by lobbying efforts of companies claiming to be at risk of carbon price leakage to prevent more ambitious climate policies.

Figure 1 demonstrates how this framework could be applied to sectors. The spider diagrams show that the farther the scoring is from the center, the more optimal level for that specific indicator. The comparison of diagrams shows how heavy emissions-intensive industries are more likely to have optimal conditions for policymakers to consider using offsets as cost containment measures for unavoidable emissions than land-based transport. Please note that as this assessment is done at the global level, categories of indicators related to policy and actor's abatement capacity are not included.

Figure 1: Comparing sectors according to whether they have optimal conditions for using offsets according to different success factors



Source: South Pole. Note: This interpretation is subject to stringency of compliance policies that determine whether cost containment measures are necessary. Furthermore, the scoring of indicators is also based on a global assumption of technological baselines, and therefore policymakers will need to undertake a domestic scoring exercise for each indicator to determine if emissions from sectors can truly be considered hard-to-abate in the country.

Mitigation activities that could supply offsets

Mitigation activities that can supply offsets are those that are currently inaccessible to local actor's due to lack of access to technology, finance or capabilities. These mitigation activities could be made accessible through benefiting from finance and technology transfer provided through being able to sell offsets (Warnecke et al. 2018). However, it should also be noted that the sale of offsets must not lead to negative environmental and social effects. Indeed, offsets that provide environmental and social contributions should be promoted.

Table 2 provides an evaluation framework that policymakers can use to determine whether a mitigation activity can benefit from the offset mechanism to realize inaccessible emissions and sustainable development contributions, while still not being at risk of undermining environmental integrity. The 'optimal level' indicated in the table below therefore refers to when it is likely that offsets will add value while also upholding environmental integrity of the compliance scheme.

Table 2: Summary of the optimal level for factors to be successful in qualifying mitigation activity for offsets supply

Category	Success factors	Optimal level for offsets supply
Policy-related	NDC coverage	Low NDC coverage: means the mitigation activity is outside the scope of the NDC
	Climate policy coverage	Low climate policy coverage: means the mitigation activity would not be realized by existing climate policies
	Carbon pricing coverage	High carbon prices: means there is the business case to realize the mitigation activity if its suggested abatement costs are lower than the carbon price
Technical	Maturity of low-carbon technologies and penetration in the market	Medium-high maturity: indicates that technical barriers are overcome to realize emission reductions Low-medium penetration: demonstrates that mitigation is not widely deployed, demonstrating technological additionality.
	Size of the technical mitigation potential	High size of emission reductions: could be significant if mitigation activities are implemented
Economic	Mitigation cost of technologies	Medium costs of mitigation: indicate that mitigation activities need additional financing in order to be realized and would be attractive if the cost of abatement is lower than the suggested carbon price.
	Carbon price responsiveness	Medium-high carbon price responsiveness: means that offset suppliers are willing and able to respond to supplying offsets when there is a financial incentive to reward them for realized such mitigation
Actor's abatement capacity	Financial resources	Low financial resources: means sectoral actors have low financial resources to implement mitigation activities and can benefit from offset financing
	Technical know how	Low technical know-how: sectoral actors lack knowledge capabilities to implement mitigation activity and can benefit from implementation experience of the mitigation activity

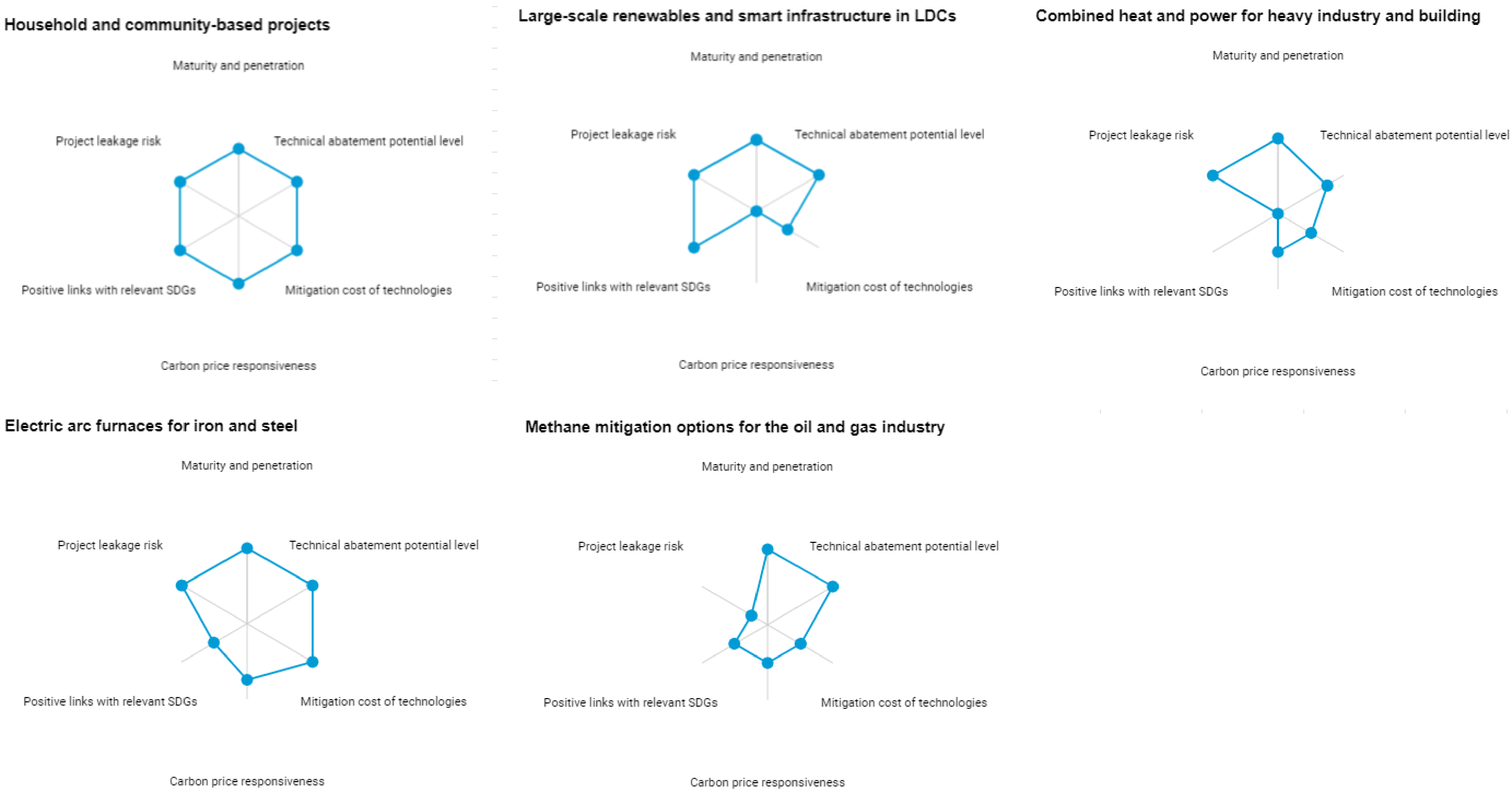
Category	Success factors	Optimal level for offsets supply
Environ-mental and social	Positive links with relevant SDGs	High chance of realized SDGs: Mitigation activity can realize several SDG co-benefits and does not undermine sustainable development
	Project leakage risk	Low risk of project leakage: Efforts to ensure mitigation within the project boundary will not result in emissions increasing outside the project boundary (e.g. increased deforestation rates outside the territorial boundary of a stand-alone REDD+ project, that can cause harm to neighboring ecosystems and communities)
Policy-related	NDC coverage	Low NDC coverage: the mitigation activity is outside the scope of the NDC
	Climate policy coverage	Low Climate policy coverage: the mitigation activity would not be realized by existing climate policies
	Carbon pricing coverage	High Carbon pricing coverage: Incentives to realize the mitigation activity if its suggested abatement costs are lower than the carbon price

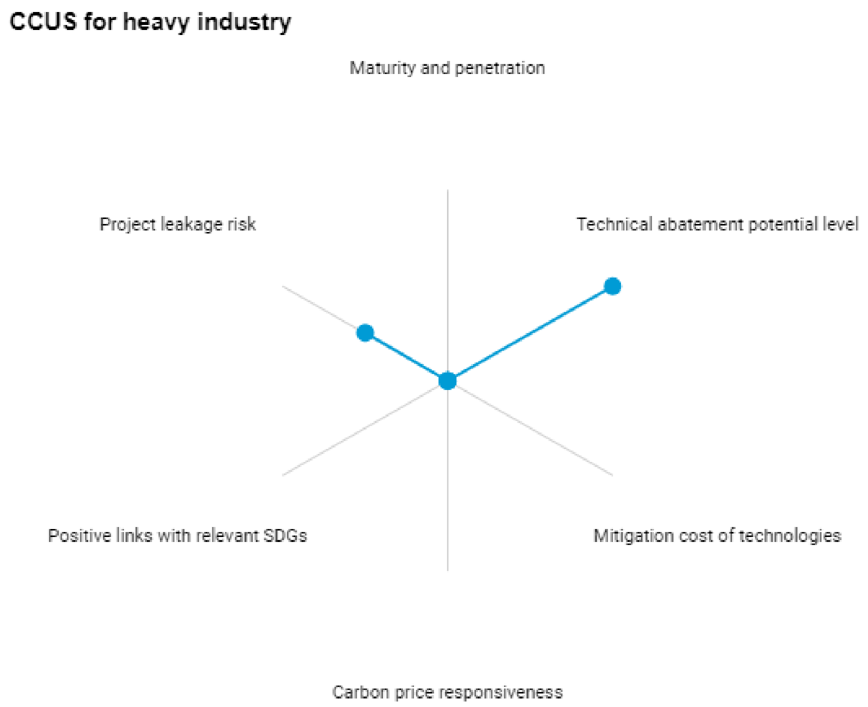
Source: South Pole

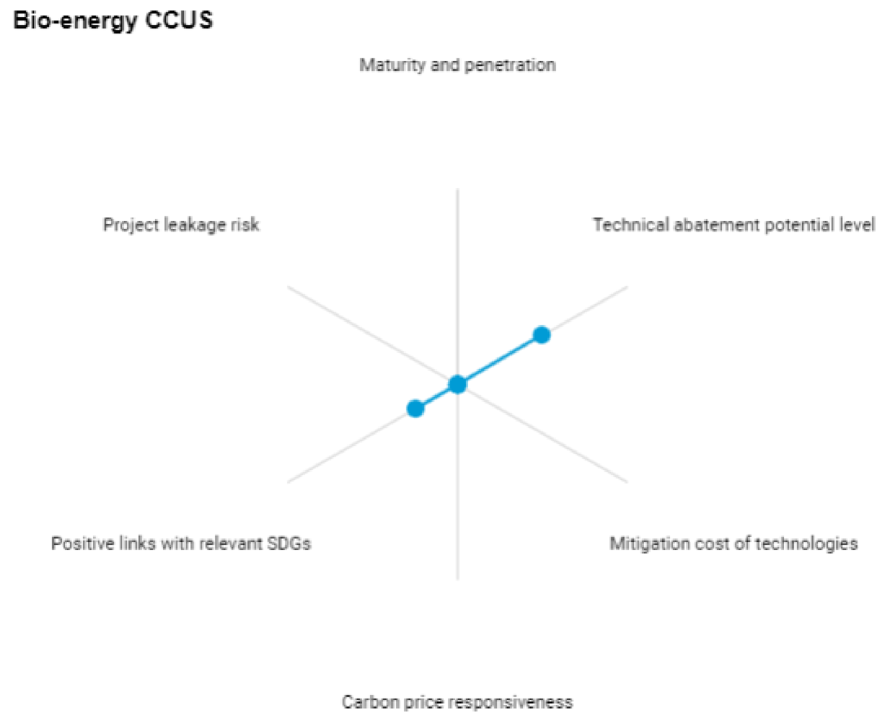
Figure 2 below demonstrates how this framework could be applied to different mitigation activities, with scores that are further from the center demonstrating optimal conditions that the sector can supply offsets. Like the previous framework, these spider diagrams exclude evaluating success factors related to the categories of policy or actor's abatement capacity as these cannot necessarily be assessed at the global level.

As can be seen below, projects that support financing in Least Developed Countries, along with carbon financing for electric arc furnaces, are likely to have optimal scores across different success factors that demonstrate offsets can add value while upholding environmental integrity. In contrast, projects involving carbon capture utilization and storage (CCUS) are currently too expensive, particularly as current carbon prices imposed by governments are too low to support the business case for financing these projects through the offset mechanism. Similarly, CCUS technologies need to have strong monitoring, reporting and verification systems in place to ensure there is no leakage of emissions outside the scope of the project boundary, and to ensure emissions are permanently stored. Other industrial applications, such as combined heat, power (CHP), and cooling for heavy industry, district heating and building are likely to be benefit from offsets in the context of countries where these technologies are not the norm, and where policies are unlikely to be updated to actors to install CHP technologies.

Figure 2: Evaluation of different mitigation activities for supplying offset







Source: South Pole. Note: While the results of this assessment are based on global averages, it must be undertaken in the context of the jurisdiction's technological, capacity and policies to determine if mitigation activities are truly inaccessible.

Practical evaluation steps through technological baseline setting and roadmap determination

While the research team has analyzed literature at a global level to demonstrate how an evaluation framework (as demonstrated in the tables above) could be used on specific sectors and technologies, determining whether offsets can add-value while ensuring environmental integrity is highly country-specific in terms of existing technologies, policies and private sector capacity.

The most important solution to address this knowledge gap is to assist policymakers in developing a technological baseline and roadmap that can provide an in-country assessment that takes into account country-specific factors. This will allow to determine which sectoral emissions are hard-to-bate because they are unavoidable or too costly, and which emission reductions are inaccessible. Hence, these steps could inform policymakers in determining which sectors should be allowed to use offsets and which mitigation activities could benefit from supplying offsets. The steps to develop a sectoral baseline and technological roadmap include:

Step 1: Identifying the current sectoral baseline

Policymakers should undertake an on-the-ground survey to understand what are the predominant technologies used in the sector to then calculate their emissions-intensity. This can help a country understand its current sectoral baseline.

Step 2: Developing a technological roadmap by determining which emissions are not hard-to-abate

Policymakers should compare the best-in class technologies that are available globally (or that the country has access to) and determine which of these options are appropriate to the sectoral context of the country.

From identifying appropriate mitigation options, policymakers should consider whether these options could be realized with the right set of climate policies. As such, policymakers can then develop a technological roadmap that identifies which mitigation options could be realized with in-country efforts potentially in the next five to ten years.

Policymakers can then measure the potential emission reductions that could be achieved by these mitigation options (including with support policies) to develop a sectoral baseline.

Step 3: Identifying which mitigation options go beyond the technological roadmap and could thus benefit from the offset mechanism

Mitigation options that are beyond the current technological roadmap and are identified as being inaccessible for a given time period could benefit from supplying offsets to realize emission reductions in a given time period.

The emission reductions that are hard-to-abate due to lack of mitigation options (or costs) could be eligible to demand offsets as a cost-containment measure to adverse economic effects of a strong compliance regime.

By undertaking the exercise of sectoral baselines and technological roadmaps, policymakers can gather the necessary information needed to determine whether and how offsets can be incorporated into a compliance scheme. International climate finance can play a very important role in helping policymakers determine the baselines and roadmaps for their respective jurisdictions. This exercise also provides policymakers with the necessary clarity on how much they can raise their ambition with the incorporation of offsets – thereby providing greater transparency on whether and how offsets can uphold environmental integrity.

Key observations and outlook

The project team has developed evaluations frameworks to assess the suitability of sectors and technologies for being included into an offset approach. The application of the frameworks at the global level indicates large differences regarding the suitability of sectors and technologies for using and generating offsets. It further highlighted the need to undertake in-country assessments that take into account national circumstances.

However, undertaking these assessments could be difficult in practice. First, consultations with experts have noted that while these sets of steps try to support policymakers in undertaking an objective assessment to identify sectors and mitigation activities that could benefit from the offset mechanism, this exercise is likely to undergo significant political debates and challenges that could ultimately lead to more subjective decision-making. The challenge of undertaking a more objective assessment is compounded due to a lack of data, and uncertainties on how emissions could evolve in the future in light of technological and commercial breakthroughs.

Greater research is needed to develop practical approaches for addressing this challenge. Developing a sectoral baseline and technological roadmap can be an important capacity-building process to get clarity on the scope and level of NDC targets for policymakers over time. For supplying offsets, one practical approach is to issue priority lists of which mitigation activities are identified as being additional within a given time period (e.g. World Bank Partnership for Market Readiness with Peru). Though undertaking these practical steps can be challenging, it can provide greater transparency and clarity of how compliance schemes can raise ambition and ensure environmental integrity, particularly when qualifying which sectors could demand offsets, and which mitigation activities can supply offsets.

Zusammenfassung

Politische Entscheidungsträger*innen, die die Möglichkeit der Anrechnung von anderweitig erzielten Klimaschutzzertifikaten (Offsets) im Rahmen von Kohlenstoffbepreisungssystemen in Erwägung ziehen, müssen festlegen, welche Sektoren und Aktivitäten auf Nachfrage- und Angebotsseite des geplanten Offset-Ansatzes einbezogen werden sollen. Um die Faktoren und Indikatoren zu erforschen, die politische Entscheidungsträger*innen bei diesem Prozess unterstützen können, sollten zwei Perspektiven in Betracht gezogen werden:

Aus **Perspektive der Nachfrageseite** stellt sich die Frage, welche Sektoren (oder Anlagen innerhalb eines Sektors) schwer zu vermeidende Emissionen verursachen und daher für die Verwendung von Offsets als Kostendämpfungsmaßnahmen in Frage kommen könnten, um nachteilige wirtschaftliche Auswirkungen zu vermeiden.

Aus **Perspektive der Angebotsseite** stellt sich die Frage, welche Technologien von der Finanzierung durch den Kohlenstoffmarkt profitieren könnten, um Emissionsreduktionen zu realisieren, die ansonsten aufgrund von technologischen, finanziellen oder anderen Barrieren nicht zugänglich sind.

Ziel dieses Berichts ist es, Bewertungsrahmen zur Verfügung zu stellen, die politischen Entscheidungsträgern* Entscheidungsträgerinnen als Leitfaden dienen, um Folgendes zu identifizieren: (1) **„Schwer zu reduzierende“ Emissionen** (Identifikation jener Sektoren/Anlagen, die für die Nachfrage nach Offsets in Frage kommen) im Vergleich zu jenen, die leicht zu reduzieren sind; und (2) **Minderungsoptionen, die nicht zugänglich sind** (um jene Minderungsaktivitäten zu identifizieren, die Offsets liefern könnten) im Vergleich zu denen, die zugänglich sind (und daher den Kohlenstofffinanzierungsmechanismus nicht benötigen, um umgesetzt zu werden). Die Bewertungsrahmen liefern Kategorien von Erfolgsfaktoren, die die Wahrscheinlichkeit angeben, dass Offsets einen Mehrwert schaffen und die ökologische Integrität der Kohlenstoffbepreisungssysteme aufrechterhalten. Dieser Bericht wendet diese Bewertungsrahmen anschließend auf ausgewählte Sektoren und Minderungsoptionen an. Hiermit sollen politische Entscheidungsträger*innen dabei unterstützt werden, eine Bewertung vorzunehmen, welche Sektoren oder Minderungsoptionen sich am ehesten für die Einbindung in einen Offset-Ansatz – auf Nachfrage- oder auf Angebotsseite – eignen. Dieser Bericht ist Teil des Forschungsvorhabens „Analyse der Vor- und Nachteile von Offset-Ansätzen in ausgewählten Sektoren – FKZ 3719 42 507 0“, dessen finalen Ergebnisse in drei separaten Berichten festgehalten wurden. Er baut auf den Fallstudien, die in dem Bericht *Offset approaches in existing compliance mechanisms - Adding value and upholding environmental integrity?* von Carvalho et al. (2021)dargestellt werden und nutzt zudem den konzeptionellen Ansatz, der in dem Bericht *Suitability and success factors of offsets post 2020* von Kreibich et al. (2021) entwickelt wurde.

Es ist zu beachten, dass diese Bewertungsrahmen für eine Beurteilung auf globaler Ebene entwickelt wurden. Die Berücksichtigung länderspezifischer Faktoren (wie z. B. die Politik, die aktuelle sektorale/technologische Landschaft und die Vermeidungskapazität der Akteure* Akteurinnen) kann zu unterschiedlichen Ergebnissen in Bezug auf die Eignung von Offsets für das jeweilige Land führen.

Sektoren, die sich für die Nachfrage von Offsets eignen könnten

Sektorale Emissionen, die schwer zu reduzieren sind, sind solche, die aufgrund fehlender und unausgereifter Technologien technisch unvermeidbar sind. Dies bedeutet, dass die Kosten für eine Reduzierung prohibitiv hoch wären und in einem ambitionierten Kohlenstoffbepreisungssystem zu negativen wirtschaftlichen Folgen führen würden, wie z.B. Carbon Leakage. Carbon Leakage beschreibt eine Situation, in der die Auferlegung von CO_2-Kosten für industrielle Emittenten einen komparativen Vorteil für Firmen bietet, die nicht mit

dem gleichen Kohlenstoffpreis konfrontiert sind, wodurch ein Anreiz für die inländische Produktion geschaffen wird, sich in Länder ohne Kohlenstoffpreis zu verlagern. Darüber hinaus kann es inländischen Akteuren*Akteurinnen an finanziellen Ressourcen oder technologischem Know-how mangeln, um innovativ zu sein oder die besten Minderungsoptionen zu implementieren. Zusätzlich könnte es heimischen Akteuren an finanziellen, oder technologischen Mitteln fehlen, um weitere Reduzierungsmaßnahmen zu entwickeln oder best-in-class Beispielen zu folgen. Aufgrund des Risikos von Carbon Leakage, haben politische Entscheidungsträger vollständige, oder partielle Ausnahmen von dem Compliance-System für Sektoren mit schwer zu reduzierenden Sektoren ermöglicht. Um jedoch für Compliance-Akteure in diesen Sektoren Anreize zu schaffen, in langfristige Strategien zur Dekarbonisierung ihres Betriebs zu investieren, müssen politische Signale gesetzt werden, um zu zeigen, dass solche Kostendämpfungsmaßnahmen nur Übergangsmaßnahmen sind.

Tabelle 1 bietet einen Bewertungsrahmen, den politische Entscheidungsträger*innen nutzen können, um zu bestimmen, ob es einem Sektor (oder bestimmten Anlagen) erlaubt sein sollte, Offsets zu nutzen, um ambitioniertere Anforderungen zu erfüllen. Die Bewertung basiert auf der Identifizierung der optimalen Bedingungen für bestimmte Indikatoren.

Tabelle 1: Zusammenfassung des optimalen Niveaus zur Offset-Nachfrage nach Erfolgsfaktoren

Kategorie	Erfolgsfaktor	Optimales Niveau für die Offset-Nachfrage
Politik-bezogen	NDC-Abdeckung Abdeckung der Klimapolitiken Abdeckung der CO2-Bepreisung	Hohe politische Ambition: NDC-Ziele, nationale Politiken und die Bepreisung von Kohlenstoff decken sektorale Emissionen ab, die in Bezug auf Umfang und Ambition schwer zu erreichen sind, was die Notwendigkeit von Maßnahmen zur Kostenbegrenzung impliziert, um höhere Ambitionen erfüllen zu können.
Technisch	Technologische Reife und Marktdurchdringung	Geringe Reife: Minderungsoptionen haben keine kommerzielle Reife, um ohne Weiteres zur Reduzierung sektoraler Emissionen eingesetzt zu werden.
	Minderungsvolumen	Geringes Volumen der Emissionsminderung: Das Volumen der Emissionsreduzierung, das durch identifizierte Minderungsoptionen für den Sektor erreicht werden könnte, wäre nicht signifikant genug, um die Ziele zu erreichen.
Ökonomisch	Minderungskosten	Hohe Dekarbonisierungskosten: Die Kosten der Minderungsoptionen sind aufgrund der hohen Vorlaufkosten für Kapital und Betrieb erheblich.
	Reaktionsfähigkeit auf CO_2-Bepreisung	Geringe Reaktionsfähigkeit auf Kohlenstoffpreise: Die Akteure*Akteurinnen des Sektors reagieren kaum auf Compliance-Regelungen/Kohlenstoffpreise, da die Kosten der Dekarbonisierung höher sind als die der Compliance.
	Carbon Leakage-Risiko	Hohes Carbon Leakage-Risiko: Die Anlagen sind dem Risiko von Carbon Leakage ausgesetzt, da sie sehr emissionsintensiv und dem Handel ausgesetzt sind.[2]

[2] Politische Entscheidungsträger*innen könnten Quantifizierungsbewertungen nutzen, die von der Europäischen Union entwickelt werden, um festzustellen, ob Anlagen aufgrund des vorgeschlagenen Kohlenstoffpreises von einer Verlagerung des Kohlenstoffpreises bedroht sind. Dies kann politische Verzerrungen verhindern, die durch Lobbying-Bemühungen von Unternehmen verursacht werden, die behaupten, von einer Verlagerung des Kohlenstoffpreises bedroht zu sein, um ehrgeizigere Klimapolitik zu verhindern.

Kategorie	Erfolgsfaktor	Optimales Niveau für die Offset-Nachfrage
Minderungs-kapazität der Akteure*innen	Finanzielle Ressourcen	Geringe finanzielle Ressourcen: Compliance-Akteure*Akteurinnen haben nicht die finanziellen Ressourcen, um Minderungsoptionen einzusetzen, und würden daher hohe Compliance-Kosten für Emissionen zahlen, die technisch unvermeidbar sind.
	Technisches Knowhow	Geringes technisches Know-how: Geringer Zugang zu technischem Wissen, das für den Einsatz von Minderungsoptionen erforderlich ist (wahrscheinlich auch aufgrund der mangelnden Reife der Technologie).

Abbildung 1 zeigt, wie dieser Rahmen auf Sektoren angewendet werden könnte. Je weiter die Punktzahl von der Mitte der Spinnendiagramme entfernt ist, desto optimaler ist das Niveau für diesen spezifischen Indikator. Der Vergleich der Diagramme zeigt, dass emissionsintensive Schwerindustrien eher über optimale Bedingungen für politische Entscheidungsträger*innen verfügen, die Verwendung von Offsets als Kostendämpfungsmaßnahmen für unvermeidbare Emissionen in Betracht zu ziehen, als der landgestützte Verkehr. Dabei muss beachtet werden, dass Kategorien von Indikatoren, die sich auf die Politik und die Vermeidungskapazität der Akteure*Akteurinnen beziehen, nicht berücksichtigt wurden, da die Bewertung auf globaler Ebene erfolgte.

Abbildung 1: Vergleich von Sektoren hinsichtlich ihrer Bedingungen für die Nutzung von Offsets nach verschiedenen Erfolgsfaktoren

Quelle: South Pole. Hinweis: Diese Interpretation ist abhängig von der Strenge der Compliance-Instrumente, die bestimmen, ob Kostendämpfungsmaßnahmen notwendig sind. Darüber hinaus basiert die Bewertung der Indikatoren auf einer globalen Annahme von technologischen Basiswerten. Daher müssen die politischen Entscheidungsträger*innen für jeden Indikator eine nationale Bewertung vornehmen, um festzustellen, ob die Emissionen von Sektoren im Land tatsächlich als schwer zu reduzieren angesehen werden können.

Minderungsaktivitäten, die Offsets anbieten könnten

Minderungsaktivitäten, die Offsets liefern können, sind solche, die derzeit für lokale Akteure*Akteurinnen unzugänglich sind, weil sie keinen Zugang zu Technologie, Finanzen oder die erforderlichen Fähigkeiten haben. Diese Minderungsaktivitäten könnten zugänglich gemacht werden, indem sie von Finanzmitteln und Technologietransfer profitieren, die durch den Verkauf von Offsets bereitgestellt werden. Es sollte jedoch auch beachtet werden, dass der Verkauf von Offsets nicht zu negativen ökologischen und sozialen Auswirkungen führen darf. Vielmehr sollten jene Maßnahmen gefördert werden, die ökologische und soziale Beiträge liefern.

Tabelle 2 bietet einen Bewertungsrahmen für politische Entscheidungsträger*innen, um zu bestimmen, ob eine Minderungsaktivität vom Offset-Ansatz profitieren kann. Es werden Minderungsoptionen identifiziert, die unter anderen Umständen unzugänglich wären und Nachhaltigkeitswirkungen erzielen, ohne dabei Gefahr zu laufen, die Umweltintegrität zu untergraben. Das in der folgenden Tabelle angegebene „optimale Niveau" bezieht sich daher darauf, wann es wahrscheinlich ist, dass Offsets einen Mehrwert schaffen und gleichzeitig die Umweltintegrität des Compliance-Instruments aufrechterhalten.

Tabelle 2: Zusammenfassung des optimalen Niveaus der Offset-Bereitstellung, um eine erfolgreiche Qualifizierung von Minderungsaktivitäten zu erreichen

Kategorie	Erfolgsfaktoren	Optimales Niveau für die Offset-Bereitstellung
Politik-bezogen	NDC-Abdeckung	Geringe NDC-Abdeckung. Die Minderungsaktivität liegt außerhalb des Geltungsbereichs des NDCs.
	Abdeckung der Klimapolitiken	Geringe Abdeckung durch die Klimapolitik. Die Minderungsaktivität würde durch die bestehende Klimapolitik nicht realisiert.
	Kohlenstoffpreis-abdeckung	Hohe Kohlenstoffpreise. Es gibt ein Geschäftsmodell, um die Minderungsaktivität zu realisieren, wenn die vorgeschlagenen Vermeidungskosten niedriger sind als der Kohlenstoffpreis.
Technisch	Technologische Reife und Marktdurchdringung	Mittel-hoher Reifegrad. Technische Barrieren können überwunden werden, um Emissionsreduktionen zu realisieren. Geringe-mittlere Durchdringung. Die Emissionsminderung ist nicht weit verbreitet, was die technologische Zusätzlichkeit demonstriert.
	Größe des Minderungspotentials	Großer Umfang der Emissionsreduzierung: mögliche Bedeutung für die Umsetzung von Minderungsmaßnahmen.
Ökonomisch	Minderungskosten der Technologien	Mittlere Kosten der Minderungen. Minderungsaktivitäten benötigen zusätzliche Finanzierung, um realisiert zu werden, und wären attraktiv, wenn die Kosten der Minderung niedriger sind als der vorgeschlagene Kohlenstoffpreis.
	Reaktionsfähigkeit auf CO_2-Bepreisung	Mittlere bis hohe Reaktionsfähigkeit auf den Kohlenstoffpreis. Die Anbieter von Ausgleichsmaßnahmen sind bereit und in der Lage, Ausgleichsmaßnahmen zu liefern, wenn es einen finanziellen Anreiz gibt, der sie für die Realisierung solcher Ausgleichsmaßnahmen belohnt.
Minderungs-kapazität	Finanzielle Ressourcen	Geringe finanzielle Ressourcen. Sektorale Akteure*Akteurinnen verfügen über geringe finanzielle Ressourcen, um

Kategorie	Erfolgsfaktoren	Optimales Niveau für die Offset-Bereitstellung
der Akteure*Akteurinnen		Minderungsaktivitäten umzusetzen und können von der Finanzierung durch Offsets profitieren.
	Technisches Knowhow	Geringes technisches Knowhow: Sektoralen Akteuren*Akteurinnen fehlt es an Wissenskapazitäten zur Umsetzung von Minderungsaktivitäten und sie können von der Erfahrung bei der Umsetzung der Minderungsaktivität profitieren.
Ökologisch und Sozial	Positive SDG-Bezüge	Hohe Wahrscheinlichkeit für Beiträge zur SDGs-Umsetzung: Die Minderungsaktivität kann mehrere SDG-Beiträge realisieren und untergräbt nicht die nachhaltige Entwicklung
	Risiko von Verlagerungseffekten	Geringes Risiko für Verlagerungseffekten: Es bestehen Maßnahmen um Sicherzustellen, dass die Minderungsmaßnahmen innerhalb der Projektgrenzen nicht dazu führen, dass die Emissionen außerhalb der Projektgrenzen zunehmen (z. B. erhöhte Abholzungsraten außerhalb der territorialen Grenzen eines eigenständigen REDD+-Projekts, die benachbarten Ökosystemen und Gemeinden Schaden zufügen können)

Source: South Pole

Abbildung 2 zeigt, wie dieser Rahmen auf verschiedene Minderungsaktivitäten angewandt werden könnte. Werte, die weiter von der Mitte entfernt sind, zeigen optimale Bedingungen, unter denen der Sektor Offsets zur Verfügung stellen kann. Wie das vorherige Rahmenwerk schließen diese Spinnendiagramme die Bewertung von Erfolgsfaktoren aus, die mit den Kategorien der Politik oder der Minderungskapazität der Akteure*Akteurinnen zusammenhängen, da diese nicht notwendigerweise auf globaler Ebene bewertet werden können.

Wie unten zu sehen ist, haben Projekte, die die Finanzierung in den am wenigsten entwickelten Ländern unterstützen, sowie Projekte zur Finanzierung elektrischer Lichtbogenöfen voraussichtlich optimale Werte für die verschiedenen Erfolgsfaktoren. Sie zeigen, dass Offsets einen Mehrwert schaffen und gleichzeitig die Umweltintegrität wahren können. Im Gegensatz dazu sind Projekte, die Kohlenstoffabscheidung, -nutzung und -speicherung (CCUS) beinhalten, derzeit zu teuer, insbesondere da die aktuellen, von Regierungen auferlegten Kohlenstoffpreise zu niedrig sind, um ein Geschäftsmodell für die Finanzierung dieser Projekte durch den Offset-Mechanismus zu unterstützen. Ebenso müssen CCUS-Technologien über starke Monitoring-, Reporting- und Verifizierungs-Systeme verfügen, um sicherzustellen, dass keine Emissionen außerhalb der Projektgrenzen entweichen und dass die Emissionen dauerhaft gespeichert werden. Andere industrielle Anwendungen wie Kraft-Wärme-Kopplung (KWK) und Kühlung für die Schwerindustrie, Fernwärme und Gebäude werden wahrscheinlich von Offsets im Kontext von Ländern profitieren, in denen diese Technologien nicht die Norm sind und in denen es unwahrscheinlich ist, dass die Politik angepasst wird, um Anreize für die Installation von KWK-Technologien zu schaffen.

Abbildung 2: Bewertung verschiedener Minderungsaktivitäten nach ihren Bedingungen zur Bereitstellung von Offset

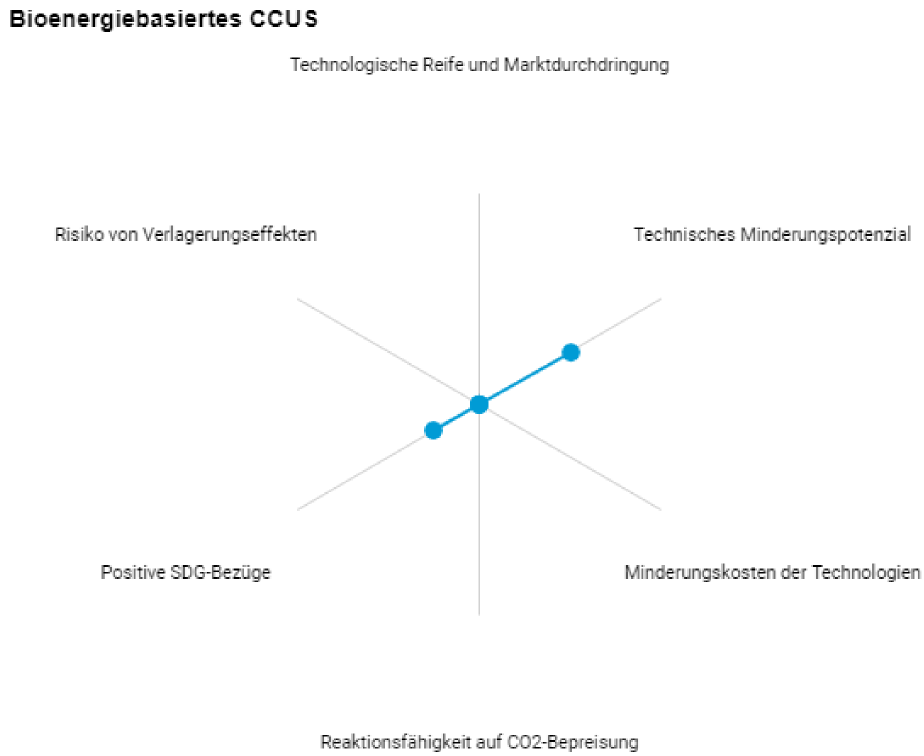
Haushalts - und Gemeindebasierte Projekte

Großangelegte Erneuerbare Energien und intelligente Infrastruktur in LDCs

Kraft-Wärme-Kopplung für Schwerindustrie, Fernwärme und Gebäude

Elektrolichtbogenöfen für Eisen und Stahl

Methan Vermeidungsoptionen für die Öl und Gas Industrie



Quelle: South Pole. Hinweis: Die Ergebnisse dieser Bewertung beruhen auf globalen Durchschnittswerten. Daher muss eine Bewertung im Kontext der technologischen, kapazitären und politischen Gegebenheiten des Landes vorgenommen werden, um festzustellen, ob Minderungsmaßnahmen tatsächlich unzugänglich sind.

Praktische Bewertungsschritte durch Festlegung eine technologischen Referenzfalls und eines Fahrplans

Das Forschungsteam hat Literatur zusammengetragen, um zu zeigen, wie ein Bewertungsrahmen (wie in den obigen Tabellen 1 und 2 dargestellt) auf bestimmte Sektoren und Technologien angewendet werden könnte. Demgegenüber ist die Bestimmung, ob Offsets einen Mehrwert schaffen und gleichzeitig die Umweltintegrität gewährleisten können, im Hinblick auf die bestehenden Technologien, die Politik und die Kapazitäten des Privatsektors sehr länderspezifisch.

Der wichtigste Ansatz, um diese Wissenslücke zu schließen, ist die Unterstützung der politischen Entscheidungsträger*innen bei der Entwicklung eines technologischen Referenzfalls und eines Fahrplans, der eine länderspezifische Bewertung unter Berücksichtigung der länderspezifischen Faktoren ermöglicht. Auf diese Weise lässt sich feststellen, welche sektoralen Emissionen nur schwer zu reduzieren sind, weil sie unvermeidbar oder zu kostspielig sind, und welche Emissionsreduktionen nicht erschlossen werden können. Daher könnten diese Schritte den politischen Entscheidungsträgern*Entscheidungsträgerinnen bei der Entscheidung helfen, welche Sektoren die Verwendung von Offsets erlauben sollten und welche Minderungsaktivitäten von der Bereitstellung von Offsets profitieren könnten. Die Entwicklung eines sektoralen Referenzfalls und eines technologischen Fahrplans umfasst die folgenden Schritte:

Schritt 1: Identifizierung des aktuellen sektoralen Referenzfalls

Eine Vor-Ort-Erhebung ermöglicht es politischen Entscheidungsträgern* Entscheidungsträgerinnen, zu verstehen, welche Technologien in dem Sektor vorherrschen, um anschließend deren Emissionsintensität zu berechnen. Dies kann einem Land dabei helfen, seine aktuelle sektorale Ausgangssituation zu begreifen.

Schritt 2: Entwicklung eines technologischen Fahrplans durch die Bestimmung nicht schwer zu reduzierender Emissionen

Der Vergleich der besten Technologien, die weltweit verfügbar sind (oder zu denen das Land Zugang hat) ermöglicht es, zu bestimmen, welche dieser Optionen für den sektoralen Kontext des Landes geeignet sind.

Nach der Identifizierung geeigneter Minderungsoptionen ist von den politischen Entscheidungsträgern*innen zu prüfen, ob diese Optionen mithilfe klimapolitischer Maßnahmen realisiert werden können. Somit können politische Entscheidungsträger*innen einen technologischen Fahrplan entwickeln, der aufzeigt, welche Minderungsoptionen mit landesinternen Anstrengungen in den nächsten fünf bis zehn Jahren realisiert werden könnten.

Politische Entscheidungsträger*innen können anschließend die potenziellen Emissionsreduktionen messen, die durch diese Minderungsoptionen erreicht werden können (auch mit unterstützenden Maßnahmen), um einen sektoralen Referenzfall abzuleiten.

Schritt 3: Identifikation jener Minderungsoptionen, die über den technologischen Fahrplan hinausgehen und somit vom Offset-Mechanismus profitieren könnten

Minderungsoptionen, die jenseits des aktuellen technologischen Fahrplans liegen und als nicht erreichbar für einen bestimmten Zeitraum identifiziert werden, könnten von der Bereitstellung von Offsets profitieren, um Emissionsreduktionen in einem bestimmten Zeitraum zu realisieren.

Die Emissionsreduktionen, die aufgrund fehlender Minderungsoptionen (oder hoher Kosten) nur schwer zu realisieren sind, könnten für die Nachfrage nach Offsets als Kostendämpfungsmaßnahme gegen die negativen wirtschaftlichen Auswirkungen eines strengen Verpflichtungssystems in Frage kommen.

Durch die Anwendung sektoraler Referenzfälle und technologischer Fahrpläne können politische Entscheidungsträger*innen die notwendigen Informationen zusammentragen, um zu bestimmen, ob und wie Offsets in ein Erfüllungsregime integriert werden können. Die internationale Klimafinanzierung kann den politischen Entscheidungsträgern* Entscheidungsträgerinnen dabei helfen, die Referenzfälle und Fahrpläne für ihre jeweiligen Systeme zu bestimmen. Dieses Vorgehen verschafft den politischen Entscheidungsträgern*innen auch die nötige Klarheit darüber, um wie viel sie ihre Ambitionen durch die Einbeziehung von Offsets erhöhen können - und sorgt so für mehr Transparenz darüber, ob und wie Offsets die Umweltintegrität aufrechterhalten können.

Wichtige Beobachtungen und Ausblick

Das Projektteam hat Bewertungsrahmen entwickelt, um die Eignung von Sektoren und Technologien für die Einbeziehung in einen Offset-Ansatz zu beurteilen. Die Anwendung der Rahmenwerke auf globaler Ebene zeigt große Unterschiede hinsichtlich der Eignung von Sektoren und Technologien für die Nutzung und Erzeugung von Offsets auf. Zudem wurde die Notwendigkeit deutlich, länderspezifische Bewertungen vorzunehmen, die die nationalen Gegebenheiten berücksichtigen.

Die Durchführung dieser Abschätzungen könnte sich in der Praxis jedoch als schwierig erweisen, wie der Austausch mit Experten*Expertinnen ergeben hat. So versucht dieses Vorgehen zwar, politische Entscheidungsträger*innen bei der Durchführung einer objektiven Bewertung zu unterstützen, um Sektoren und Minderungsaktivitäten zu identifizieren, die vom Offset-Mechanismus profitieren könnten. Die Durchführung wäre jedoch voraussichtlich erheblichen politischen Debatten und Herausforderungen ausgesetzt, die letztlich zu einer eher subjektiven Entscheidungsfindung führen könnten. Die Herausforderung, eine objektivere Bewertung vorzunehmen, wird durch den Mangel an Daten und die Ungewissheit, wie sich die Emissionen angesichts technologischer und kommerzieller Durchbrüche in der Zukunft entwickeln könnten, noch verstärkt.

Es sind weitere Forschungsarbeiten erforderlich, um praktische Ansätze zur Bewältigung dieser Herausforderung zu entwickeln. Die Entwicklung eines sektoralen Referenzfalls und eines technologischen Fahrplans kann ein wichtiger kapazitätsbildender Prozess sein, um politischen Entscheidungsträgern* Entscheidungsträgerinnen Klarheit über den Umfang und die Höhe der NDC-Ziele im zeitlichen Verlauf zu verschaffen. Für die Bereitstellung von Offsets besteht ein praktischer Ansatz darin, Positivlisten darüber zu erstellen, welche Minderungsaktivitäten innerhalb eines bestimmten Zeitraums als zusätzlich angesehen werden können (siehe z.B. Partnership for Market Readiness der Weltbank für Peru). Obwohl die Durchführung dieser praktischen Schritte eine Herausforderung darstellen kann, kann sie für mehr Transparenz und Klarheit sorgen, wie Compliance-Regelungen den Ehrgeiz steigern und die Umweltintegrität gewährleisten können, insbesondere wenn festgestellt wird, welche Sektoren Ausgleichszahlungen verlangen könnten und welche Minderungsaktivitäten Ausgleichszahlungen leisten können.

1 Introduction

1.1 Background

To both achieve the temperature goals of the Paris Agreement and avoid catastrophic climate change, the world will have to reach net-zero greenhouse gas (GHG) emissions at the beginning of the second half of this century (Levin & Davis, 2019). Consequently, a number of countries and regions have committed to eliminating their net GHG emissions in the coming decades. For example, New Zealand, France, the United Kingdom (UK), Norway and Sweden have established laws to ensure their targets are met by 2050, while others, such as Canada, Chile, South Korea, Spain and the European Union (EU), have proposed net-zero targets (Energy and Climate Intelligence Unit, 2020). Japan and China have also stated net-zero targets in policy documents for 2050 and 2060, respectively (Energy and Climate Intelligence Unit, 2020). Despite these pledges, impediments to the complete decarbonisation of the world economy abound.

One key challenge is reducing emissions in economic sectors that are currently hard to abate. Abatement challenges occur due to immature and expensive low- and zero-carbon technologies, the poor substitutability of carbon-intensive inputs (including fuels), sunk costs in new facilities that are carbon-intensive and 'locked-in' infrastructure. Absent dramatic technological innovations and support for deployment, these sectors will almost certainly continue to emit GHGs into the atmosphere for the foreseeable future. Governments will therefore need to consider how to support the long-term decarbonisation of these hard-to-abate sectors through green industrial policies that support the innovation, development and deployment of low-carbon technologies and processes.

Until low-carbon options are widely available and the costs of these options decrease so that sectoral actors can implement them in their operations, it is unlikely that these actors can meet stringent emission reduction targets, or pay high carbon prices, without experiencing adverse economic or competitiveness effects. Currently, hard-to-abate sectors experience either full or partial exemptions from stringent compliance schemes (via climate targets or carbon pricing). However, policy signals need to be put in place to incentivize compliance actors in these sectors to invest in long-term strategies for decarbonising their operations. Recognising that these sectors are *currently* hard-to-abate, policymakers can use cost-containment measures, such as allowing offsets to be surrendered for compliance, to mitigate adverse economic consequences to domestic actors in the interim period, such as carbon leakage. These offsets can be generated by emission reduction, avoidance or removal activities.

Carbon leakage refers to the phenomenon in which firms shift production to jurisdictions with less stringent climate policies as a result of the imposition of a carbon pricing scheme in the original location (European Commission, n.d.). Carbon leakage is problematic for two reasons. First, it results in adverse economic consequences for the original jurisdiction. Second, it represents an environmental failure for the sector, as the global carbon footprint of the sector remains at similar levels (or could even increase) as production shifts to more carbon-intensive jurisdictions with less stringent climate policies. As such, the environmental integrity of climate action at the global level for the sector is undermined through the imposition of a more stringent climate policy in just one jurisdiction.

Policymakers wanting to decarbonize hard-to-abate sectors can consider multiple instruments to support their decarbonisation. These include 'carrots' such as low-carbon subsidies and industrial policies to support innovation and deployment of these technologies. It can also include 'stick' policies, such as regulation that imposes stringent climate targets and carbon prices to provide a long-term policy signal to these sectors that it is in their best interest to decarbonize to reduce their current and future compliance costs. While using a mix of policies is important to ensure long-term decarbonisation of hard-to-abate sectors, this report presents a methodology to assess whether these sectors need cost-containment measures, such as offsets, to meet stringent policies.

While some sectors and specific mitigation activities face significant challenges to decarbonisation, others have mitigation options that are relatively cost-effective. However, even though these mitigation options are cost-effective, there could be other barriers as to why they have not been implemented. In certain economic sectors, such as agriculture and forestry (for conservation activities that avoid the release of emissions from cutting down forests), mitigation options are difficult to implement due to economic issues (e.g. limited financial capacity for actors working in the sector and strong economic drivers for carbon-intensive practices such as deforestation), limited administrative capacity to impose stringent carbon price (e.g. complicated MRV systems with many actors involved), and/or politically sensitive with regards to imposing a carbon price. Due to this limited capacity, it is difficult to enact stringent climate policies for these sectors. Therefore, the inaccessibility of realising these mitigation options makes these sectors hard-to-abate from a political and capacity perspective.

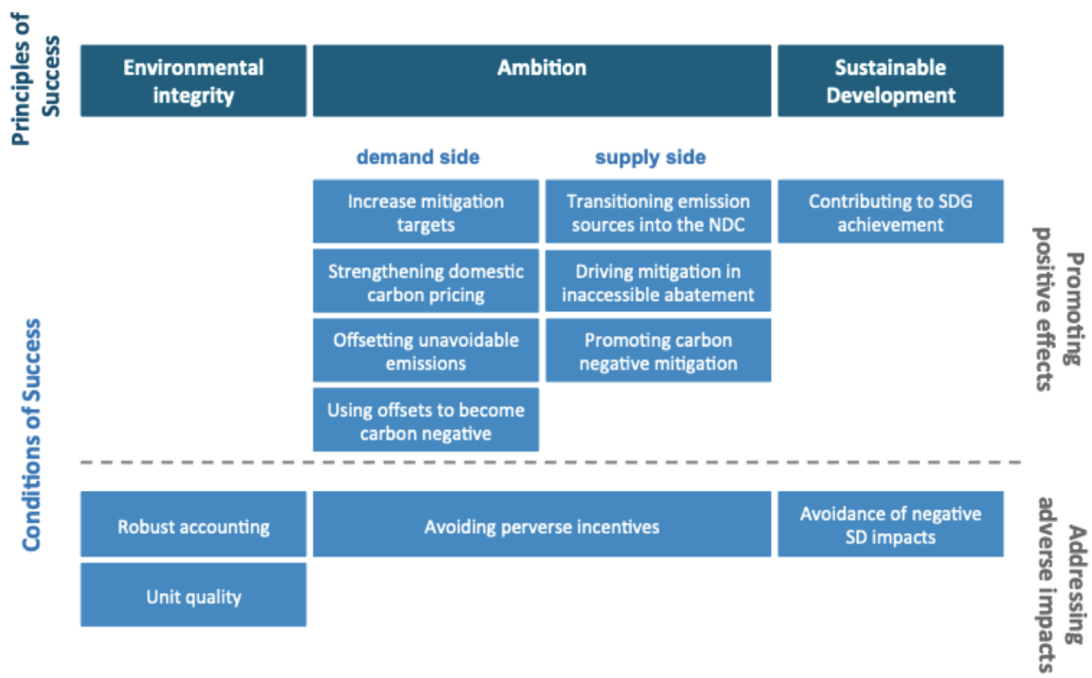
Sectors that are difficult to impose stringent climate policies to decarbonize – but have significant and cost-effective abatement potential – could benefit from supplying offsets. Offset projects provide technical capacity building by helping actors implement mitigation activities and learn how to measure, report and verify emissions from these activities. Offsets also provide an additional source of financing through the sale of certified mitigation outcomes and emissions removals in these sectors, which could be particularly relevant for not yet accessible technologies from a technical and economic point of view. Governments can also undertake sectoral crediting programmes as a way of defining which mitigation activities would go beyond the existing policy and technical efforts that define the sectoral baseline. Through a sectoral crediting approach, mitigation activities that are additional to this baseline can support more transformative efforts for the sector. Allowing these mitigation activities to supply offsets can provide policymakers the flexibility to drive emission reductions for abatement opportunities that are otherwise inaccessible, with the potential to eventually include these sectors under future compliance schemes once the technical capacity to abate is built up.

Sectoral crediting approaches identify mitigation activities that go beyond the sectoral baseline, and therefore could be 'credited' by qualifying for the supply of offsets. These additional efforts should target mitigation that is currently inaccessible due to a lack of technical and financial capacity among actors to undertake such mitigation action. Policymakers could consider whether there are policy interventions other than offsets that could support making these options accessible, such as providing subsidies or tax breaks that incentivize such deployment. If policymakers consider these policy interventions, then they should be reflected in a more stringent sectoral baseline. If these policy interventions are not implemented, the inaccessible mitigation options could be considered as crediting activities that are certified as offsets. It should also be noted that specific low-carbon mitigation activities in sectors within a compliance scheme could supply offsets as long as this mitigation activity would not have been realized under the compliance scheme. For example, specific mitigation activities realized in compliance actor's own companies could be considered for offset supply if they go beyond the mitigation objective set by compliance scheme. Allowing these mitigation activities to be eligible for offset supply can help make these inaccessible abatement options more accessible by providing the necessary financing and implementation experience needed to help decarbonize compliance sectors.

1.2 Objective

The ultimate aim of this report is to support policymakers in the process of identifying sectors that could qualify to use offsets to meet compliance and pinpointing mitigation activities that could qualify to supply offsets. This study draws on lessons learnt from historical case studies (as presented in WP1) and principles and conditions to guide the use of offsets to help meet post-2020 compliance (as presented in Kreibich et al., 2021 and illustrated in Figure 3).

Figure 3: Principles of success for post-2020 offset approaches



Source: Wuppertal Institute

Therefore, the concrete objectives of this report are:

- to identify success factors that can help determine whether specific sectors and specific mitigation activities in selected sectors could qualify to generate demand for or supply of offsets, which can be incorporated into a methodology that can serve as a basis for policymakers to undertake their own assessment of sectors within the policy and development context of the country; and
- to do a deep dive into shortlisted mitigation activities at the global-level to serve as an example of the application of the methodology and to demonstrate their potential.

1.3 Scope: selected sectors and specific mitigation activities in selected sectors for this study

An initial literature review assessment led to a short-listing of sectors and mitigation activities to assess their potential for qualifying to buy or develop offsets after 2020 respectively, as can be seen in Table 3. From the demand side, sectors were selected based on literature reviews that identify that these sectors are currently hard-to-abate, and therefore, could need cost-containment measures as an interim measure before more stringent climate policies can be developed. For the supply-side, a more granular approach was taken to consider specific mitigation activities that could support accessing inaccessible abatement in a post-2020 context and provide environmental and social co-benefits. These sectors were not necessarily chosen because they have the highest abatement potential, but because they receive a lot of interest in policy discussions, and demonstrate different aspects that policymakers must consider when choosing whether to make these options eligible as offsets.

Table 3: Shortlist of selected sectors and specific mitigation activities in selected sectors

Demand (selected sectors)	Supply (specific mitigation activities in selected sectors)
1. Heavy industry: aluminum, cement, iron and steel, certain petrochemicals (including plastics) 2. Heavy land-based transport	1. Residential a. Household or community-based projects 2. Power a. Large-scale renewables and smart infrastructure in Least Developed Countries (LDCs) b. Bio-energy carbon capture, utilization and storage (CCUS) 3. Heavy industry a. Combined heat and power (CHP) and for heavy industry b. CCUS for heavy industry c. Electric arc furnaces for iron and steel 4. Oil and gas a. Mitigation of upstream emissions from oil and gas extraction (if linked through the same sector on the demand side)

Source: South Pole

It is important to note that, despite being relevant for this study, two sectors have been excluded from this analysis for the following reasons:

- natural climate solutions (NCSs): these solutions are explored within other German Environment Agency (UBA)-funded projects; and
- aviation and shipping: due to potential conflict with both the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) and the homologous scheme under consideration for the maritime sector, as well as a previous Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU)-funded research on carbon pricing options for international maritime emissions.

Section 2 of this report presents the above-mentioned methodology. Section 3 applies the methodology to two shortlisted sectors for demand and seven mitigation activities for supply (identified in the next subsection). In addition, section 3 includes design considerations that policymakers should take into account to ensure a successful incorporation of offsets. Section 4 consolidates the results and provides key recommendations for policymakers to evaluate whether and how offsets could be incorporated into compliance schemes as an interim measure to achieve long-term decarbonisation of hard-to-abate sectors.

It is important to keep in mind that Kreibich et al. (2021) argued that offsets should only be incorporated into a compliance scheme when they are able to uphold environmental integrity and increase the ambition of the compliance scheme while promoting sustainable development – thereby meeting all three principles of success. A single principle of success cannot be achieved at the expense of another if the offset approach is to be considered successful. This report also recognizes that the success factors that justify the use of offsets now could change in the future as the challenges for decarbonisation are overcome. Consequently, offsets should only be used as an interim measure for compliance schemes.

2 Methodology to assess suitability of offsets in compliance schemes

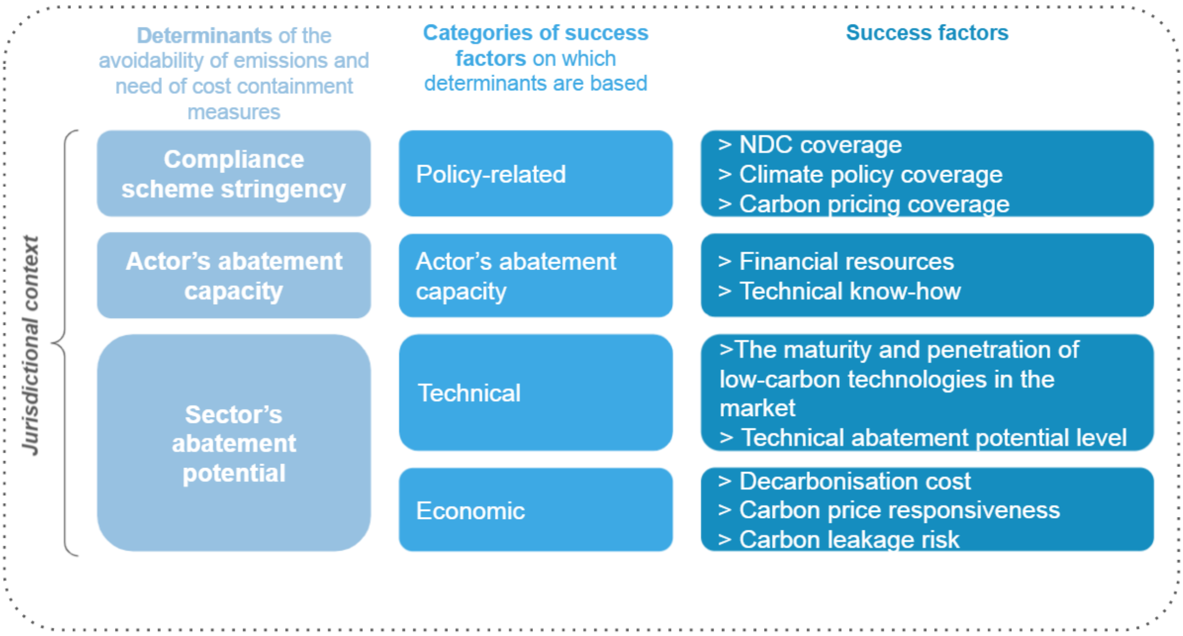
The introduction of this report discusses how to assess whether sectors should be eligible to demand offsets or specific mitigation activities to supply offsets. This section considers how this underlying rationale can be operationalized through a methodological framework that uses specific success factors identified in *Offset approaches in existing compliance mechanisms—Adding value and upholding environmental integrity?* (Carvalho et al. 2021) and on the conceptual approach developed in the report *Suitability and Success Factors of Offsets post 2020* (Kreibich et al. 2021). These frameworks are developed to help policymakers assess whether the optimal levels for different success factors are in place within their own jurisdictional context for offsets to realize the principles and conditions of success, as developed in Kreibich et al. (2021), and illustrated in Figure 3. Therefore these evaluation frameworks assess whether offsets have the optimal levels in each factor to successfully add-value to compliance schemes by raising its ambition and promoting sustainable development without undermining the environmental integrity of the compliance scheme.

This section of the report will explain how policymakers can undertake these assessments for themselves. It is very important for policymakers to undertake this assessment themselves, as country-specific characteristics that relate to the policy and technological landscape of a jurisdiction could alter whether or not sectors or mitigation activities are eligible to demand or supply offsets.

2.1 Sectors that could qualify for demanding offsets

Sectors are likely to qualify for demanding offsets when their emissions are hard-to-abate. Hard-to-abate sectors are those with emissions that are technically unavoidable. In addition, there might be sectors where emissions are technically avoidable, but where the costs of abating would be prohibitively high and lead to adverse economic consequences, justifying the use of cost-containment measures to avoid such effects, particularly if paying stringent compliance costs could trigger carbon leakage. This central thesis is related to factors that shape how stringent and ambitious a compliance scheme would be, the compliance actor's capacity to abate, along with factors that affect the abatement potential of a sector. While each of these factors is shaped by the context of the country, this subsection will help policymakers consider how to assess whether their respective sectors would need cost-containment measures based on the interplay of these factors. Figure 4 outlines the different determinants, categories and their associated success factors that can identify whether a sector needs cost-containment measures. It is followed by Table 4, which indicates the optimal level for each factor in order to be successful in determining whether a sector could qualify for using offsets to meet compliance.

Figure 4: Demand-side methodology overview



Source: South Pole

Table 4: Summary of the optimal level of success factors for a sector to qualify for offsets demand

Category	Success Factor	Optimal level for offsets demand
Policy-related	Nationally Determined Contribution (NDC) coverage	High
	Climate policy coverage	High
	Carbon pricing coverage	High
Actor's abatement capacity	Financial resources	Low
	Technical know how	Low
Technical	Maturity of low-carbon technologies and penetration in the market	Low
	Technical abatement potential level	Low
Economic	Decarbonisation cost	High
	Carbon price responsiveness	Low
	Carbon leakage risk	High

Source: South Pole

2.1.1 Policy-related: determining the stringency of compliance schemes

Policymakers should only incorporate offsets into a compliance scheme if they are willing to introduce stringent and ambitious compliance schemes and invest in the development of robust governance institutions and infrastructure to enable compliance actors to be able to use offsets as a cost-containment measure while still upholding the environmental integrity of the compliance scheme. Determining whether compliance schemes are ambitious enough to justify cost containment measures can be difficult to assess and are often subjective. Therefore, the following sub-section provides policymakers with a guide to think about the nexus between the stringency of the compliance scheme and the other categories of success factors to determine whether sectors can demand offsets.

Compliance schemes encompass the NDC targets, domestic climate policies and domestic carbon pricing policies that are imposed on sectors. The stringency of compliance schemes is determined by whether the ambition level is high enough, and the coverage wide enough, to cover emissions from sectors that are currently unavoidable due to low technical abatement potential, leading to high economic costs of abatement. Abatement potential is defined as volume of emission reductions that could be achieved by implementing sectoral mitigation options. Furthermore, it can be determined by taking into consideration whether the cost of meeting the policy requirements (e.g. performance standards of facilities) or paying the carbon price would actually lead to carbon leakage.

Policymakers would have to assess whether these emissions are unavoidable based on the compliance actor's capacity to abate, along with the sector's abatement potential (as addressed in the next subsections). Therefore, compliance schemes are considered to be unambitious and weakly stringent if they do not address emissions from sectors that actually are avoidable, or the compliance price signal is so low that it would not incentivize actors to reduce avoidable emissions. Sectors thus do not need offsets as cost-containment measures. Conversely, compliance schemes are considered to be ambitious and strongly stringent if they provide both short- and long-term incentives to compliance actors to reduce avoidable emissions and **cover unavoidable emissions – thus justifying the use of offsets as cost containment measures.**

When determining the stringency of a compliance schemes, policymakers need to consider all the policies that would be implemented for that sector and how the mix of these policies would determine the stringency of the compliance scheme to justify the use of cost-containment measures, such as offsets, as interim measures. While this kind of policy assessment can be done at the country level, it is challenging to do at the global level the aggregated information would bear little significance for each separate scheme and would have a short shelf life, as countries are currently updating their NDCs and continuously revising existing and creating new climate policies. Therefore, policy-related factors are not used in the in-depth sectoral analysis in section 3, which discusses the use of offsets as a cost-containment measures for specific sectors.

2.1.2 Actor's capacity to abate

Certain sectors can be hard-to-abate if firms, communities or individuals do not have the capacity or resources needed to implement emission reduction or sequestration activities. These abatement capacities are dependent on a number of factors, including know-how and access to finance, low-carbon technologies and information. While it is difficult to determine an actor's capacity to abate at the sectoral level, it is well recognized that it is likely that countries that are less economically developed will have limited financial resources, access to technologies and skills to realize the technical mitigation potential, even for relatively mature mitigation options with high global penetration rates. These countries with low economic development, such as LDCs, could consider allowing the use of offsets as a way to help sectors meet stringent compliance schemes. According to Net Zero Tracker, countries such as Sudan, South Sudan, Somalia and Sierra Leone are discussing the setting of net-zero targets; in this case, allowing sectors to use offsets could be interim solutions until decarbonisation solutions that are commercially available in other markets can be implemented by domestic actors (Energy and

Climate Intelligence Unit, 2020). As the determination of whether this factor is likely to be successful is specific to the context of the jurisdiction, it will not be assessed in section 3.1 in the in-depth profiles for offset demand sectors.

2.1.3 Technical factors that affect the abatement potential of the sector

The first category of success factors that determine whether the sector is hard-to-abate is the technical potential to mitigate is low. Sectors have low technical potential to mitigate when the volume of emissions that can be reduced is relatively small. These volumes can be low due to the maturity and penetration of low-carbon technologies and processes are low to yield a small volume of emissions that could be reduced. The following considers how policymakers can assess the technical abatement potential for sectors.

2.1.3.1 Technical abatement potential level of the sector

Each sector also has a portfolio of mitigation options, with each mitigation option being able to reduce a certain volume of the sector's emissions. Therefore, not all sectors have the same technical abatement potential based on the availability of mitigation options. Another factor that affects a sector's technical abatement potential is the emissions intensity of technologies in a country, and the amount of economic activity in the sector. Again, undertaking a technological assessment in the country, including implementing monitoring, reporting and verification (MRV) systems in sectors, will be important for estimating the size of sectoral emissions in a country and the potential emission reductions that could be achieved by implementing mitigation options that are appropriate for the country's sector.

The combination of undertaking a sectoral technological assessment, roadmap of mitigation options, and measuring emission reductions for selected mitigation options would essentially create a long-term emissions baseline for the sector. This sectoral baseline would help the policymaker assess whether a sector should be eligible for offsets, based on whether sectoral actors could feasibly meet targets based on the volume of emissions that could be realized from commercially available mitigation options. Barring dramatic technological advancements, sectors that could reduce a limited volume of emissions could be eligible to demand offsets. In contrast, those sectors that have the technical feasibility to curb large emission volumes are less likely to need offsets, unless the economic costs of mitigation are high (see next subsection). Over time, these sectoral baselines would need to be updated as technologies mature, thereby making those sectoral emissions that were previously hard-to-abate now emissions that sectoral actors could reduce.

For the purposes of undertaking this analysis at a global level, sectors' technical abatement potential is assessed based on the values provided in McKinsey's "Pathways to a low-carbon economy" (McKinsey & Company, 2009). The report assesses the abatement potential of the following sectors: power, petroleum and gas, cement, iron and steel, chemicals, other industry, transport, buildings, waste, forestry, and agriculture. Although the "Pathways to a low-carbon economy" report was published in 2009, it is used in this report because it is the only source that allows for a *quantitative* comparison of different sectors' technical abatement potentials. More up-to-date comparisons of sectors' technical abatement potentials were unable to be found. Where possible, sectors' technical abatement potentials as stated in the report were cross-checked with more recent and sector-specific studies.

Scoring of sectors' technical abatement potential level is conducted as follows:

- low: if the abatement potential is up to two-thirds of the mean value of all sectors assessed in the McKinsey report;

- medium: if the abatement potential is between two-thirds of the mean value and one-third above the mean value of all sectors assessed in the McKinsey report; or
- high: if the abatement potential is greater than one-third above the mean value of all sectors assessed in the McKinsey report.

This methodology is employed for the sake of comparative scoring of sectors at the global level in section 3 but is less useful for in-country assessments. It would be important for policymakers to survey the current technological landscape of the sector to determine the current baseline and the size of abatement that could be achieved if the appropriate mitigation options could be deployed. Policymakers should determine which parts of a sector's emissions are hard-to-abate based on their abatement potential *and* economic costs.

2.1.3.2 The maturity and penetration of low-carbon technologies in the market

This success factor is determined by whether the potential mitigation options for a sector are mature enough to be used by compliance actors easily, and therefore could easily reach high penetration rates. Maturity of a mitigation option refers to the viability of the technology/process to be incorporated into the operations of a sector to lead to actual mitigation, or whether these technologies are still more at the 'idea' or 'prototype' stage, and therefore, are not ready for large-scale deployment.

To assess whether this factor is successful for a sector at the global level, this report uses the Technology Readiness Level (TRL) assessment as applied by the International Energy Agency (IEA) to "over 400 individual technology designs and components across the whole energy system that contribute to achieving the goal of net-zero emissions" (IEA, 2020). The IEA classifies technologies as belonging to one of the following 11 different TRLs,[3] with low numbers signifying immature and low penetration and higher numbers referring to more commercially viable technologies.

In this analysis, for sectors where the IEA identifies several different clean energy technologies that could be undertaken by the sector, the median TRL ranking for technologies associated with that sector is selected to determine the maturity, and suggested penetration, of low-carbon technologies in those sectors. The scoring of sectors' maturity and penetration of low-carbon technologies, as per the IEA, is conducted as follows:

- low: if the median technology has a score of 1-4, classified by the IEA as being at the idea to early prototype stage, and therefore has low likelihood that it will be mature enough to have high penetration in the near future (an example include nuclear fusion and wave energy converters, which harness the energy contained in the movement of waves to generate electricity);
- medium: if the median technology has a score of 5-10, these technologies have achieved more mature prototypes and some commercial viability, though it has not yet reached the proof of stability stage to suggest easy deployment in compliance sectors without further testing (such as improved biomass cooking stoves and floating offshore wind turbines); or
- high: if the median technology has a score of 11, it suggests there are sufficient mitigation options in the sector that have reached the proof of stability stage, and therefore, the sector

[3] The TRL scoring is: (1) = initial idea; (2) = application formulated; (3) = concept needs validation; (4) = early prototype; (5) = large prototype; (6) = full prototype at scale; (7) = pre-commercial demonstration; (8) = first-of-a-kind commercial; (9) = commercial operation in relevant environment; (10) = integration needed at scale; or (11) = proof of stability reached.

does have options that are mature enough to enable mitigation in the near future (for example, light-emitting diode lights and onshore wind projects).

Unfortunately, the IEA's survey of technologies does not cover mitigation options for all sectors. Consequently, for missing data, a review of existing literature was conducted to determine the maturity of various sectors and the market penetration of low-carbon technologies.

Though this assessment was done at the global sectoral level, it would be important for policymakers to undertake an assessment of the types of mitigation options that would be suitable for their country, and the associated penetration rates of these mitigation options. In other words, policymakers would need to survey the technologies that are currently used by actors in the sector to compare the technologies currently used in the country and their penetration rates against the best-in-class low-carbon technologies for that sector. This would provide policymakers with a technological assessment of the 'baseline' for the country. Countries who have best-in-class mitigation technologies in their sectors may only be able to further decarbonize their sectors once the immature technologies become more commercially viable. In this case, sectors in these countries should be able to use cost-containment measures such as offsets.

However, for sectors in countries that have a low penetration of commercially viable mitigation options, policymakers would need to consider *why* these mitigation options are not yet deployed. These could be due to several reasons, such as: (1) compliance actors do not have the financial or technical capacity to implement these mitigation options, (2) lack of technology transfer, (3) lock-in to carbon-intensive infrastructure or (4) simply actor inertia unless a policy incentive, such as a stringent compliance scheme, would mandate such deployment.

For reasons 1 to 3, policymakers can provide support policies to help actors to decarbonize their sectors and allow compliance actors to use offsets as an interim measure until these mitigation options are actually implemented. To make sure offsets do not delay the actual implementation of these mitigation options, policymakers would need to create a technological roadmap that considers how this sector could deploy commercially viable technologies, including appropriate support policies to overcome hurdles for deployment. The technological roadmap could provide time periods and undertake regular assessments on the deployment of these mitigation options, and therefore, help the policymaker assess when offsets can be used as an interim measure and when it is appropriate to stop due to a greater penetration of these commercially viable technologies. For the last reason (reason 4: compliance actor inertia), a stringent compliance scheme would be sufficient to incentivize deployment, without the need for cost-containment measures.

2.1.4 Success factors to determine economic costs

In some sectors, high decarbonisation costs, low responsiveness to carbon pricing mechanisms and/or concerns over carbon leakage represent high economic costs to the sector, and could therefore justify cost-containment measures. It should be noted those technical and economic costs factors are highly interrelated – as technologies that lack maturity, penetration and have low abatement potential are likely to have high economic costs.

2.1.4.1 Sectoral decarbonization cost

In this report, **'decarbonization costs'** refers to the monetary costs associated with the deployment or adoption of available technologies to reduce sectoral GHG emissions. The size of the decarbonisation costs for a sector can vary from jurisdiction to jurisdiction, based on the kinds of technologies that are already put in place, the penetration rates of best-in-class mitigation technologies and the financial capability of firms to invest in such mitigation measures.

For jurisdictions that already have best-in class-technologies largely deployed, the costs of further decarbonization for the sector are expected to be high as the number of available mitigation options is limited to very expensive technologies. These sectors could therefore qualify for the use of offsets until the costs of these mitigation options decrease. For jurisdictions that have a low penetration rate of commercially available technologies, the question would be whether support policies (e.g. subsidies) would help compliance actors deploy such technologies or send compliance signals strong enough to incentivize the deployment of these technologies. These sectors are unlikely to need offsets to meet compliance, as the costs of mitigation are not high enough or can be overcome through other support measures if the financial capacity of actors is low.

To undertake a global assessment in the selected sectors (section 3), the study has undertaken proxy classification on the suggested decarbonisation cost for the sector. This is done by assessing the most viable mitigation options for the sector and determining the magnitude of their upfront capital requirements. For example, some mitigation options in a sector can be implemented only with a large amount of capital upfront, whereas others can be implemented with a substantially smaller amount of capital. Building new facilities with low-carbon equipment to replace existing facilities exemplify the former, while the adoption of energy-saving behavioural changes in the trucking sector, such as reducing braking and idling, typify the latter.

Based on a literature review (Åhman,n.d; de Pee et al., 2018; Energy Transitions Commission, 2018; EURACTIV, 20189; Friedmann et al., 2019) of the types of mitigation options for a sector, the decarbonisation costs for a sector are scored in the following way:

- high: most decarbonization options have high upfront costs due to building new facilities and/or large-scale infrastructure, or the literature review (Åhman,n.d; de Pee et al., 2018; Energy Transitions Commission, 2018; EURACTIV, 20189; Friedmann et al., 2019) acknowledges the installation of new equipment is currently extremely expensive (CCUS for existing facilities);
- medium: when the most financially viable decarbonization alternative involves the installation of new equipment, construction of small-scale infrastructure, refurbishment of existing facilities or low-carbon substitutes that are considered to be expensive; and
- low: the switching costs of inputs are relatively low

While this kind of proxy classification is used for the purposes of this report, it would be important for policymakers to assess the 'threshold' under which decarbonisation costs are considered to be significant enough to warrant the need for cost-containment measures. If the decarbonisation costs for a sector are considered to be high – particularly due to high upfront costs that would have a 'lag' period until emissions are actually reduced – policymakers could allow offsets as an interim measure.

2.1.4.2 Carbon price responsiveness

Carbon price responsiveness refers to the availability of mitigation options that companies in the sector can implement to reduce emissions in their operations, thereby reducing the volume of emissions for which they would have to pay a carbon price. Sectors that are considered to have low carbon price responsiveness are unable to respond, or respond very minimally, to carbon prices because their carbon-intensive inputs have low substitutability (e.g. clinker for cement) or they are 'locked in' to carbon-intensive infrastructure.

Based on a literature review (NewClimate Institute, 2017; Acworth et al, 2020) of mitigation options available for various sectors, sectors have been classified as belonging to one of the following three categories of carbon price responsiveness:

- low: economic sectors are very unresponsive to carbon prices due to the costs of decarbonization being higher than the carbon price. The costs of decarbonization for these sectors can be high due to reasons such as high carbon intensity, a high dependence on fossil fuels as feedstocks and 'locked-in' infrastructure;
- medium: economic sectors are moderately responsive to carbon pricing mechanisms, as there are some low-carbon substitutes to switch to, but at a cost that is greater than the carbon price; or
- high: economic sectors are responsive to carbon prices due to the relative ease and cost-effectiveness with which they can, for example, substitute carbon-intensive fuels for low-carbon alternatives and implement operational changes that reduce their carbon footprint.

Policymakers would thus need to consider to what extent actors within a compliance sector would be able to respond by reducing their own emissions if carbon prices were to be introduced and increased over time. Sectors that have low or medium carbon price responsiveness could be eligible for offsets if, without cost-containment measures in place, they would face significant costs associated with decarbonisation or are at risk of carbon leakage. It is important to note that not all sectors with actors facing high carbon prices are at the risk of carbon leakage.

2.1.4.3 Carbon leakage risk

As explained earlier, **carbon leakage** refers to the phenomenon in which companies relocate production from one jurisdiction to another as a result of the imposition or strengthening of a carbon pricing mechanism. As of June 2020, all jurisdictions that have implemented an ETS have included provisions that protect their domestic firms – particularly those that belong to emissions-intensive, trade-exposed (EITE) industries – from carbon leakage (Acworth et al, 2020). To determine the risk that an economic sector will suffer from carbon leakage as a result of either the imposition or strengthening of a carbon pricing mechanism, policymakers assess a sector's emissions intensity and trade exposure. Emissions intensity is generally "measured by volume of emissions per unit of output, revenue, value-added, or profit," whereas trade exposure is typically assessed "by the total volume of imports and exports of a product relative to imports and domestic production" (Acworth et al, 2020: 6).

Policymakers should apply quantitative methods for measuring potential impacts of carbon leakage, such as the EU ETS (EU Commission, 2020) who uses these calculations to determine whether a facility can qualify as EITE, and is therefore at risk of carbon leakage. Policymakers can use this kind of methodology to assess the risk of carbon leakage in various sectors based on the stringency of policy they are willing to implement. The World Bank Partnership for Market Readiness (2015) and Dechezlepretre and Sato (2017) demonstrated that, to date, there is no evidence that carbon leakage has occurred due to carbon prices not being high enough, or sectors that are at risk of leakage benefiting from cost-containment measures. They acknowledge this risk does increase as policies become more stringent, including through carbon price increases. However, the risk of carbon leakage could decrease as more jurisdictions introduce carbon pricing at equivalent stringency, thereby having cross-border harmonisation of carbon prices.

Based on a review of existing literature, the carbon leakage risk of sectors is classified as follows:

- **high:** sectors that were regularly classified as an EITE sector and are therefore unable to pass on carbon pricing costs without risking carbon leakage;
- **medium:** there is variability in the literature on whether this sector is classified as an EITE sector or at risk of carbon leakage; or
- **low:** sectors are well-recognized as being able to pass on cost increases to its consumers – such as the electricity sector – without losing international competitiveness.

Sectors with high and medium risk of carbon leakage were considered to qualify for using offsets as a cost-containment measure to mitigate these risks.

2.2 Mitigation activities that could supply offsets

Mitigation activities that could supply offsets need to ensure they uphold environmental integrity, raise the ambition of the compliance scheme and support the achievement of Sustainable Development Goal (SDG) benefits. Achieving these principles successfully depends on understanding the stringency of policies, the capacity of actors in the potential offset supply sector to implement mitigation options without additional financial and technical support, the mitigation activity's potential to realize SDG benefits and the presence of a robust governance framework as part of the design of the offset scheme.

The first central thesis as to whether a mitigation activity is suitable to supply offsets is if the associated mitigation activities would otherwise be inaccessible without the support of the offset mechanism. There are several factors that could make a mitigation activity inaccessible (Warneke et al, 2020). First, there is a lack of policies that incentivize the deployment of these projects. Second, there are barriers that keep these mitigation activities from being deployed, even if they have shown initial technological viability but are not commercially viable to be easily adopted by actors. Third, actors themselves can lack the capacity, expertise or access needed to deploy certain technologies.

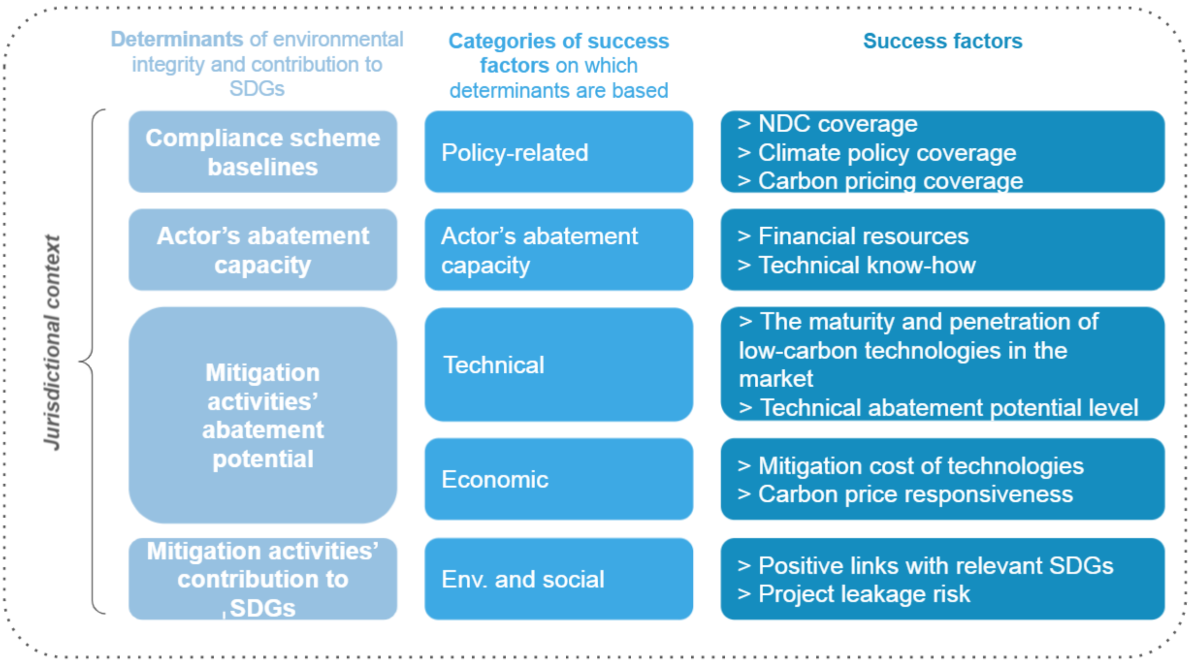
It would be important for policymakers to develop a sectoral baseline in the jurisdiction and sectors to identify which sectors qualify to supply offsets. This sectoral baseline can be in the same jurisdiction of the compliance scheme (in case policymakers wants to drive emissions reductions in domestic sectors) or outside of the jurisdiction (in cases policymakers want to support emission reductions abroad, along with finding more cost-effective supply due to high costs of abatement domestically). In the case of developing a sectoral baseline for the supply-side, this baseline can be developed either by identifying widely adopted technologies or common practice for the sector, or by the emissions intensity of the sector. Mitigation activities could thus be those that are more advanced or have lower emissions intensities. If these mitigation activities are difficult to realize (due to factors related to barriers in terms of technical, economic or actor's capacity), it could therefore allow potential supply-side actors to supply offsets to provide financing and technical support needed to implement these mitigation activities.

By developing this sectoral baseline for supply-side sectors, policymakers could then identify the mitigation activities that are inaccessible at a given time. By allowing these mitigation activities to qualify for offset supply in that time period, policymakers could then undertake sectoral crediting to demonstrate how offsets can support more transformative change for that sector, thereby raising ambition for the sector by driving mitigation in inaccessible abatement. These mitigation activities could help promote transformative change and additionally realize SDG benefits that make these mitigation options more attractive. Lastly, these mitigation activities could provide the capacity building needed to reduce the cost of abatement for these activities, allowing these emission sources to be targeted unilaterally in the future, and thereby contributing to ambition raising in the long term.

As in the previous section on 'demand-side' assessments, determining whether mitigation activities go beyond the sectoral baseline of countries requires policymakers to undertake in-country assessments. The following section provides a methodology for such an assessment. A key part of designing this approach is ensuring that these mitigation activities uphold the principle of environmental integrity. Offsets resulting from mitigation activities must also prove that they are real (i.e. that these emission reductions or removals actually occurred), additional to the sectoral baseline, measurable, permanent and do not lead to emissions being displaced to areas outside the geographical boundary of the project (so-called project leakage). If the environmental integrity of emission reductions and removals cannot be upheld through strong and robust governance frameworks involved with the verification and certification of offsets, the monitoring of the projects, and potential buffer mechanism that could address this risk, then policymakers must not include these sectors/specific mitigation activities for offset supply. Otherwise, the environmental integrity of the compliance scheme will be undermined.

While Figure 5 provides the methodological framework to structure this assessment on the grounds of identifying inaccessible abatement and upholding environmental integrity, Table 5 shows the success factors' optimal level for the specific mitigation activities of these to supply offsets.

Figure 5: Supply-side methodology overview



Source: South Pole

Table 5: Summary of the optimal level of success factors for a mitigation activity to qualify for offsets supply

Category	Success Factor	Optimal level for offsets supply
Policy-related	NDC coverage	Low
	Climate policy coverage	Low
	Carbon pricing coverage	High
Actor's abatement capacity	Financial resources	Low
	Technical know how	Low
Technical	Maturity of low-carbon technologies and penetration in the market	Maturity: medium-high maturity; penetration: low-medium penetration
	Technical abatement potential level	High
Economic	Mitigation cost of technologies	Medium
	Carbon price responsiveness	Medium-high
Environmental and social	Positive links with relevant SDGs	High
	Project leakage risk	Low

Source: South Pole

2.2.1 Policy-related factors: determining policy additionality to compliance schemes

Specific mitigation activities that would reduce emissions beyond the scope of NDC targets and are not covered under domestic climate policies, including carbon pricing schemes, could be considered to lie above the sectoral baseline. Policymakers developing a sectoral crediting mechanism would need to develop this policy baseline with a consideration of the types of policies and targets that would be put in place to form the baseline. A technological assessment would then be necessary to consider which mitigation options are within the policy scope, as the policies themselves would create the incentives to deploy these mitigation options. These mitigation options would be considered accessible and should not be eligible to supply offsets.

By identifying accessible mitigation options, policymakers could then also identify mitigation options that are still not accessible under the current (or future) policy framework, thereby suggesting mitigation options that lie outside the scope of the sectoral baseline. These sectoral baselines should be regularly updated, given that policies can and should become more ambitious over time – in terms of their scope and targets – to meet Paris targets. Therefore, the crediting mechanism could implement shorter project crediting cycles to reflect the dynamic changing of baselines. If these mitigation options become commonplace enough to be considered accessible, it would then need to come under the compliance scheme and would no longer qualify for sectoral crediting. Robust accounting frameworks need to be in place to reflect how offsets are accounted between supply and demand sectors within national and international inventories, not only to prevent double counting but also to reflect when these mitigation outcomes no longer qualify as offsets, and therefore, should only be reflected in the inventory data of the sector.

Given the heterogeneity of compliance schemes across all countries, section 3 will not assess the additionality of mitigation activities according to policy-related success factors.

2.2.2 Actor's capacity to abate

One reason why a mitigation activity may not be implemented is because there is limited capacity of firms, communities and/or individuals to implement such emission reduction and/or sequestration activities. These capacities are dependent on a number of factors, including know-how and access to finance, low-carbon technologies and information. This is therefore a very context-specific determinant, as some countries may have actors who are able to implement such mitigation options, while others do not. This report identifies two specific mitigation activities that would most likely need sectoral crediting in the LDC context. This report otherwise would discuss actor's capacity to abate in the contextual section of each sector/mitigation activity profile in Section 3, and therefore will not be scored in the profiles in Section 3.

2.2.3 Technical factors that affect abatement potential

2.2.3.1 The technical abatement potential level

The **level of the technical abatement potential** indicates sectors that do have a large potential to mitigate a larger size of emissions, but this abatement is not realized due to the limited capacity of actors, access to mitigation options or lack of support policies that could help increase the penetration of these technologies. Using offsets to realize the mitigation potential of this sector could be a good way to overcome these hurdles until these options become more likely to be included within the sectoral baseline.

The analysis in this report uses the same methodology as McKinsey & Company's (2009) "Pathways to a low-carbon economy" to measure the technical mitigation potential. Sectors that have been scored as having a high potential to mitigate should be considered for offsets, though ones with a medium score can also be considered.

2.2.3.2 The maturity and penetration of low-carbon technologies in the market

The maturity and penetration of low-carbon technologies in the market is an important success factor in determining whether the mitigation activities would go beyond the sectoral baseline. Sectors or technologies that are suitable for offset generation are those that demonstrate a level of maturity that is at the piloting stage, but not necessarily commercially viable on a project level, as can be seen by low penetration rates to be considered the 'norm' of a sector. In other words, these mitigation activities prove that they should not be considered as part of the sectoral baseline, as there is low penetration in the domestic market due to the immaturity of these technologies or the limited access that various actors have to these technologies.

This analysis also used the IEA's TRL assessment for maturity and penetration rates of technologies (along with other third-party sources), and considered mitigation options which scored 'high'. The 'high' score refers to technologies that have reached the proof of stability stage but do not necessarily have the penetration rates to be commonplace in the sector. When applied to specific countries, this assessment should be cross-referenced with maturity and penetration rates of these mitigation options in the jurisdiction that is to supply offsets.

2.2.3.3 Success factors to determine economic costs

Whether a mitigation activity should qualify for supplying offsets is in part a function of the stringency of the compliance signal on offset-demanding sectors. Offsets can only act as a cost-containment measure if they cost less than the compliance price that actors would otherwise have to pay. Carvalho et al. (2021) shows that the compliance price signal also plays a role in the carbon price responsiveness of an offset sector – where stronger and credible price signals indicate the kind of mitigation options that offset suppliers would be willing to provide as a business case exists to realize mitigation options that are otherwise economically inaccessible. Unfortunately, given that there is a wide range of compliance price signals set in countries, it is difficult to perform a comparative assessment of mitigation costs and carbon price responsiveness for different mitigation options.

Therefore, the study has used the same methodology for measuring the size of mitigation costs and carbon price responsiveness of sectors. However, the scores have different relevance with regards to determining if a mitigation activity should qualify for offset supply in terms of their impact on the overall economic costs. Mitigation activities are considered to qualify for offset supply when:

- mitigation costs are scored as medium, as these mitigation costs are in a range that could be realized through the sale of offsets. These mitigation activities need additional financing to be implemented as it involves the installation of new equipment, construction of small-scale infrastructure, refurbishment of existing facilities or deployment of low-carbon substitutes that are expensive. Sales from offset revenues could therefore cover these upfront costs. Literature reviews of the shortlisted mitigation options are used to confirm the likelihood that the offset mechanism would be sufficient to provide the necessary financing for these activities. It should be noted that this is in part a function of the prevailing compliance price. Using the offset mechanism for mitigation activities whose costs are higher than the compliance price will not be developed, continuing to make these mitigation options inaccessible;
- carbon price responsiveness is medium or high: as offset suppliers are willing and able to respond to supplying offsets when there is a financial incentive to reward them for realizing such mitigation.

2.2.4 Environmental and social factors

2.2.4.1 Achievement of Sustainable Development Goals

Beyond GHG emission reductions, activities generating offsets have proven tangible co-benefits that can be measured according to the framework of the United Nations (UN) SDGs (Figure 6) adopted in 2015. The SDGs call for urgent action by all countries cooperatively and are the overarching umbrella framework for achieving sustainable development. The SDGs help on-the-ground project impacts to be quantified and transparent.

Figure 6: Overview of the SDGs

Source: UN, 2020

Different mitigation activities contribute and are linked to different SDGs. While it is fair to assume that mitigation activities often have benefits beyond carbon pollution reductions, in some cases, negative impacts can exist. The SDG Climate Action Nexus tool shows that more than 23% of the links between the eight analysed sectors and the SDGs are trade-offs (Partnership on Transparency in the Paris Agreement, 2018).

Hence, to assess the environmental and social relevance of a given mitigation activity, it is preferable to ensure the MRV systems for projects measures positive links with the SDGs to identify those projects with greater environmental and social relevance (Day et al., 2020; Kachi et al., 2020). However, it is necessary to ensure these MRV systems have safeguards in place to avoid and minimize any potential negative social and environmental impacts. In short, they must do no harm Due to the frequency with which they have positive synergies with carbon offset projects, the following have been selected for the purpose of this study: SDGs 1 (no poverty), 2 (zero hunger), 3 (good health and well-being), 4 (quality education), 5 (gender equality), 6 (clean water and sanitation), 7 (affordable and clean energy), 10 (reduced inequalities), 14 (life below water), 15 (life on land) and 16 (peace, justice and strong institutions).

Following the same logic as the SDG Climate Action Nexus tool, an analysis of links to SDG 13 (climate action) is not included in this assessment, as this success factor aims to study the links between climate action and other co-benefits. Technologies and specific activities positively contributing to sustainable development are an attractive reason to allow them to supply offsets and can thus motivate policymakers to allow these activities to supply offsets. Apart from having substantial co-benefits beyond emissions reductions, they enjoy greater acceptance on the part of the broader public and are consequently less likely to face implementation challenges than their counterparts that do not enjoy this same acceptance.

Based on a review of existing literature and the SDG Climate Action Nexus tool, the environmental and social relevance of specific mitigation activities is classified as follows:

- Low: negative or no positive links to SDGs greater environmental and social relevance
- Medium: positive links with few SDGs with greater environmental and social relevance
- High: positive links with several SDGs with greater environmental and social relevance

2.2.4.2 Project leakage risk

Project leakage risks refers to the probability that executing a mitigation activity could lead to an increase in emissions elsewhere that are outside the boundary of the mitigation activity. The most prominent example is when increased deforestation rates are caused by the protection specific parts of a larger forest - referred to as stand-alone reduced emissions from deforestation and forest degradation (REDD+) projects. These increased deforestation rates that occur outside the territorial boundary of the stand-alone REDD+ project can cause harm to neighbouring ecosystems and communities – thus creating 'project leakage' and undermining sustainable development.

Section 3 will undertake literature review of the mitigation activity to highlight the risk of project leakage.

2.3 Existing compliance schemes that incorporate offsets

The following sub-sections provide summary tables of existing compliance schemes whose sectors can demand offsets, and compliance schemes that allow mitigation activities to be eligible supply offsets. While these table does not suggest whether these sectors should be eligible to use offsets in the post-2020 context (as the circumstances will change), it does paint a picture of the status quo.

2.3.1 Compliance schemes that allow sectors to demand offsets

Looking at implemented ETS over the globe it is interesting to note that certain sectors that are under a carbon price are allowed to use offsets more than others. A review of the 23 emissions trading schemes (ETSs) currently in operation revealed that sectors covered by carbon pricing schemes are widely allowed to demand offsets, as shown in Table 6. While offsets were eligible for compliance in the EU and Swiss ETS historically, they are not eligible for use in the current compliance period.

Table 6: Sectors allowed to demand offsets in existing ETSs and baseline-and-credit systems

Sector	Electric power	Industry	Buildings	Domestic aviation	Transport	Waste
Number and details of carbon pricing schemes that allow all covered sectors to demand offsets	**14**	**15**	**8**	**7**	**6**	**2**
	All except Tokyo and Saitama	All except the Regional Greenhouse Gas Initiative (RGGI)	Quebec, California, South Korea, Beijing, Shanghai, Shenzhen, Tokyo, and Saitama	South Korea, Fujian, Guangdong, Shanghai, Tianjin, the EU, and Switzerland (for both EU and Switzerland, offsets are no longer eligible for compliance, starting 1 January 2021)	Australia, Quebec, California, Beijing, Shanghai, and Shenzhen	Australia and South Korea

Source: South Pole based on ICAP, 2020 and the World Bank, 2020

ETSs and baseline-and-credit systems have varying rules regarding the geographic eligibility of the projects generating offsets that can be surrendered for compliance. For example, RGGI allows only offsets derived from projects in one of the participating states to be surrendered in lieu of allowances, whereas in California, offsets can be generated by not only projects located in the state but also in other US states and the Canadian province of Quebec, with whose ETS the state's cap-and-trade programme is linked. Table 7 shows the geographic eligibility of offset-generating projects in each of the ETSs and baseline-and-credit systems that allow offsets to be surrendered for compliance. As can be seen in Table 7, four schemes require all offsets to be derived from projects located within their borders and two require offsets to come from projects outside of their borders (though as of 1 January 2021, neither Switzerland nor the EU will allow offsets to be surrendered instead of allowances in their respective ETSs). The remaining 10 allow offsets to be derived from projects located both within and outside of their borders.

Table 7: Geographic eligibility of projects generating offsets eligible to be surrendered for compliance

Only offsets from external projects eligible	Only offsets from internal projects eligible	Offsets from both internal and external projects eligible
EU and Switzerland (for both countries, international offsets are no longer eligible for compliance from 1 January 2021)	RGGI, Fujian, Australia, Kazakhstan	Tokyo, Saitama, Quebec, California, South Korea, Beijing, Shanghai, Shenzhen, Guangdong, Tianjin

Source: South Pole based on ICAP, 2020 and the World Bank, 2020

2.3.2 Compliance schemes that allow mitigation activities to supply offsets

While the identification of mitigation options that could be additional from a policy perspective should be undertaken at the jurisdictional level, it is interesting to note that certain mitigation options in jurisdictions that allow offsets to be surrendered in lieu of paying the carbon price are used more than others. A review of the 23 ETSs currently in operation revealed the sectors under which these mitigation activities are covered by the aforementioned carbon pricing schemes, as shown in Table 8. It covers not only the 23 ETSs currently in operation but also carbon taxes in place in the following jurisdictions: Colombia, South Africa, Mexico and British Columbia. This table does not suggest that these sectors should be eligible to generate offsets in the post-2020 context, but it does indicate which sectors have mitigation options that could be more appropriate for sectoral crediting.

Table 8: Sectors with mitigation activities that supply offsets in existing carbon pricing schemes

Sector	Agriculture	Buildings	CCS	Chemicals	Energy and electricity	Industry	Land use, land-use change and forestry	Mining	Oil and gas	Waste
Number and details of carbon pricing schemes that allow sectors to supply offsets	**6**	**4**	**3**	**3**	**8**	**2**	**5**	**3**	**2**	**5**
	RGGI, California, Quebec, Alberta, Australia, and, South Africa	RGGI, Alberta, Tokyo, Saitama	South Korea, New Zealand and Alberta	California, Quebec, New Zealand	RGGI, New Zealand, Alberta, British Columbia, Australia, Tokyo, Saitama, and South Africa	New Zealand and Australia	RGGI, California, New Zealand, Australia South Africa, and Saitama	California, Quebec, Australia	Alberta and Australia	RGGI, Quebec, Australia South Africa, and Alberta

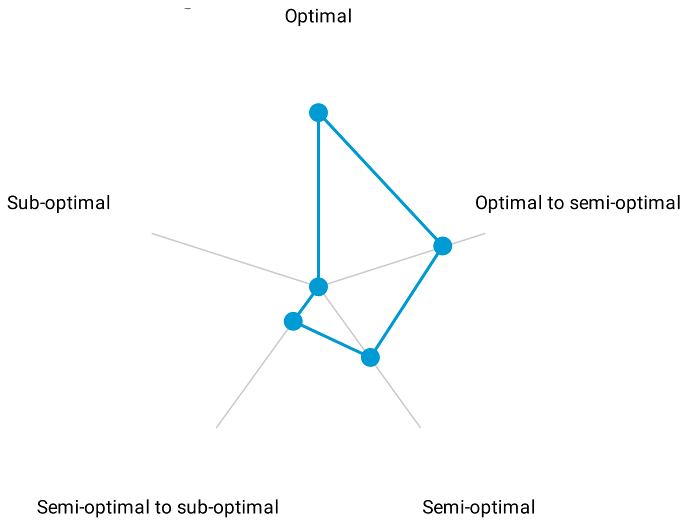
Source: South Pole based on ICAP, 2020 and the World Bank, 2020

3 Global analysis of the selected sectors and specific mitigation activities

The jurisdictional context is a fundamental piece in the methodology and can be decisive to determine if a sector or specific mitigation activity qualifies for the demand or supply of offsets under a carbon pricing scheme. However, this section applies the methodology to nine selected sectors and mitigation activities from a global perspective as a way to demonstrate how to apply this methodology in practice. It therefore omits assessments of success factors that are purely linked to the location and implementing a broad approach for the rest. Although a specific geography is not selected for this analysis, certain sectors and mitigation activities can be linked to more or less developed contexts and actors. Hence, for each sector and specific mitigation activity, a context brief is included that serves as a framework for the assessment of success factors whose optimal level is determined by context.

In addition, this section includes radar charts summarising the assessment of the demand- or supply-side factors for each of the selected sectors and mitigation activities. The radar charts provide a visual representation of the sectors' performance for each success factor, compared against the optimal levels for a sector to qualify for offsets demand or supply, as defined in section 2. Each of the axis of the radar charts represents a success factor and the blue dots represent the specific sector/mitigation activity performance values. For all success factors, the centre point of the chart represents a poor performance while the external point of the axis represents an optimal performance. The axis's middle points represent an intermediate performance as illustrated in Figure 7.

Figure 7: Radar charts explained – level of performance values



Source: South Pole

Last, this section includes design recommendations on each sector and specific mitigation activity for policymakers, who should adapt this analysis to their local context.

3.1 Demand-side

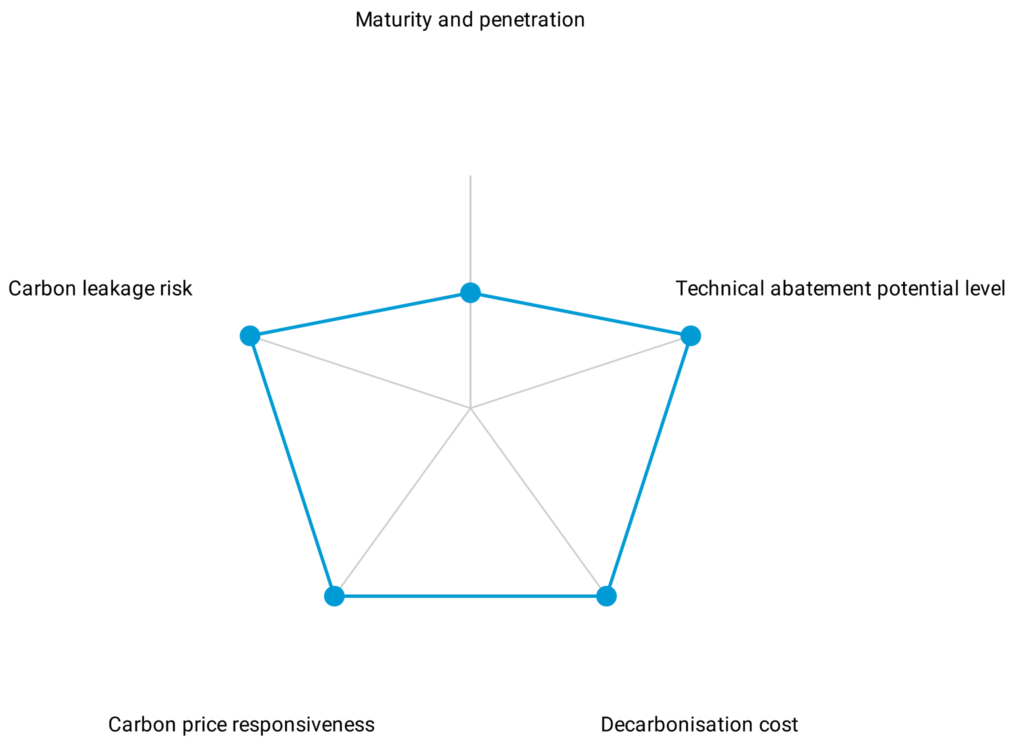
3.1.1 Heavy industry

Table 9: Sector overview - heavy industry

Heavy industry	
Sector description	In general, heavy industry involves large and heavy products and/or large and heavy equipment and facilities. In this study, heavy industry encompasses the aluminum, cement, iron, steel and certain petrochemicals (including plastics) sectors. The production of these basic materials and chemicals, such as fertilizers, is responsible for slightly more than one-fifth of global CO_2 emissions.
Context	A review of the heavy industry's capacity to abate finds that this ability is highly dependent on firms' access to finance and technical expertise. These challenges can be overcome by the government's willingness to undertake supportive policies that can make inaccessible abatement options more accessible, such as research, development, and deployment policies; low-carbon subsidies provided to sectoral actors; and strategic niche markets that can reduce the learning curve associated with these mitigation options. However, the timing under which these mitigation options will be commercially viable to reduce emissions in these sectors is not clear. Therefore, it is important for policymakers to develop baselines for each sector that can identify which mitigation options can be deployed due to imposing government policy (e.g. regulation or the carbon price); versus those mitigation options that are not mature enough to help the sector decarbonize – in which case, the use of offsets to address these hard-to-abate emissions is necessary until these mitigation options become more commercially viable.

Source: South Pole

Figure 8: Overview assessment of demand factors – heavy industry



Source: South Pole

3.1.1.1 Technical: optimal due to limited technical abatement options

The lack of technical development and limited abatement potential indicate cost-containment measures are needed, especially for actors with limited access to finance and technical capabilities. Heavy industry faces a number of technical challenges to decarbonize. Chief among these are the high temperatures integral to the production processes of sectors like steel and cement (McKinsey & Company, 2018). Due to their chemical composition and relative cost advantages, fossil fuels are combusted to generate these high temperatures: “reducing these emissions by switching to alternative fuels, such as zero-carbon electricity, would be difficult because this would require significant changes to the design of furnaces”. Other examples include energy and process related emissions in the cement industry, which is heavily reliant on the use of clinker as an intermediary product. However, clinker is carbon-intensive due to the energy intensity of the production process, along with process emissions involved with the use of limestone. Similarly, there are few substitutes for using coke (coal that is baked to remove impurities to become carbon) as a fuel and reducing agent in melting iron ore.

Many of these changes – not only to furnaces – will require significant technological advancements before they are broadly taken up. For example, the direct electrification of cement kilns is classified by the IEA (2020) as being in the early prototype stage (Stage 4). Overall, the majority of clean-energy technologies specific to the heavy industry identified by the IEA as contributing to decarbonisation fall within the 5-10 range on the agency’s TRL assessment, leading to a classification of the maturity and penetration of low-carbon technologies in the market for this sector as not being significant enough to lead to significant decarbonisation.

Overall, McKinsey's "Pathways to a low-carbon economy report" similarly finds that the technical abatement potential of many heavy industrial sectors is limited, making this sector hard-to-abate unless additional support policies are put in place to aid identified mature mitigation options (McKinsey & Company, 2009). As these sectors rely on the burning of fossil fuels to provide high temperatures, the technology that is most cited as to providing significant emissions reduction is CCUS, which is further discussed in section 3.2.5. This is an inaccessible option currently, and therefore, further confirms the current challenge of abating these sectors. Combined heat, power and cooling (aka trigeneration) is a more mature technology that also provides abatement potential for heavy industries; however, there could be other factors that limit their widespread deployment (which is discussed in section 3.2.3). Certain sectors could have more accessible mitigation options that could reduce emissions under the right circumstances, such as electric arc furnaces for the iron and steel sector (which is discussed in subsection 3.2.4).

3.1.1.2 Economic: optimal due to high decarbonisation costs

Generally speaking, heavy industry faces significant cost challenges to decarbonize on all three economic factors – decarbonization cost, carbon price responsiveness and carbon leakage risk – which explains its low carbon price responsiveness and confirms that cost-containment measures are needed. These challenges stem from a strong 'lock-in' of fossil fuel infrastructure, such as pipelines, in their production processes. For example, many heavy industrial sites require heat temperatures that so far can only be reached by burning fossil fuels. Furthermore, in many sectors that belong to the broader heavy industry category, such as steel and cement, emissions related to feedstocks – a large share of these sectors' total GHG emissions – can be abated only by altering fundamental production processes, as there are few low-carbon substitutes for these feedstocks (McKinsey & Company, 2018; Columbia University Center on Global Energy Policy, 2019). Given the difficulty in reducing emissions from the production process, the most viable way to mitigate emission is through CCUS – however these costs are high as well due to low commercial viability (Åhman, n.d).

Finally, heavy industry is widely viewed in the existing literature as facing serious carbon leakage risks due to the emissions-intensity and trade-exposed nature of many industrial sectors. Consequently, policymakers in jurisdictions that have implemented strong carbon pricing have, by and large, provided protection to these sectors through, among other mechanisms, an exemption from the carbon pricing scheme or the free allocation of emission allowances in the case of ETS. However, the ability to shield EITE industries in this manner over the long-term will be difficult in light of declining ETS allowance budgets and expansions in the scope of carbon pricing schemes, both of which are necessary to achieve net-zero GHG emissions. Thus, as allowance budgets tighten, the free allocation of allowances is reduced and the number of heavy industrial emitters subject to compliance with a carbon pricing scheme within a given jurisdiction grows, concerns about carbon leakage risks can only be expected to increase.

3.1.1.3 Design considerations

In general, heavy industry has optimal levels to potentially qualify to demand offsets. Considering the technical and economic factors analyzed in this report, raising ambition of compliance schemes could cover emissions that are hard-to-abate, and could therefore lead to a high risk of carbon leakage if other jurisdictions do not also raise their ambition. In this case, it is highly likely that heavy industry would need cost-containment measures, such as offsets, to address adverse economic consequences of raising ambition that covers unavoidable emissions.

However, it is necessary to support decarbonisation in the sector itself, particularly given its global carbon footprint. Policymakers can consider other support industrial support policies, such as research and development, or subsidies, to support implementation of mitigation activities that are not responsive to the carbon price.

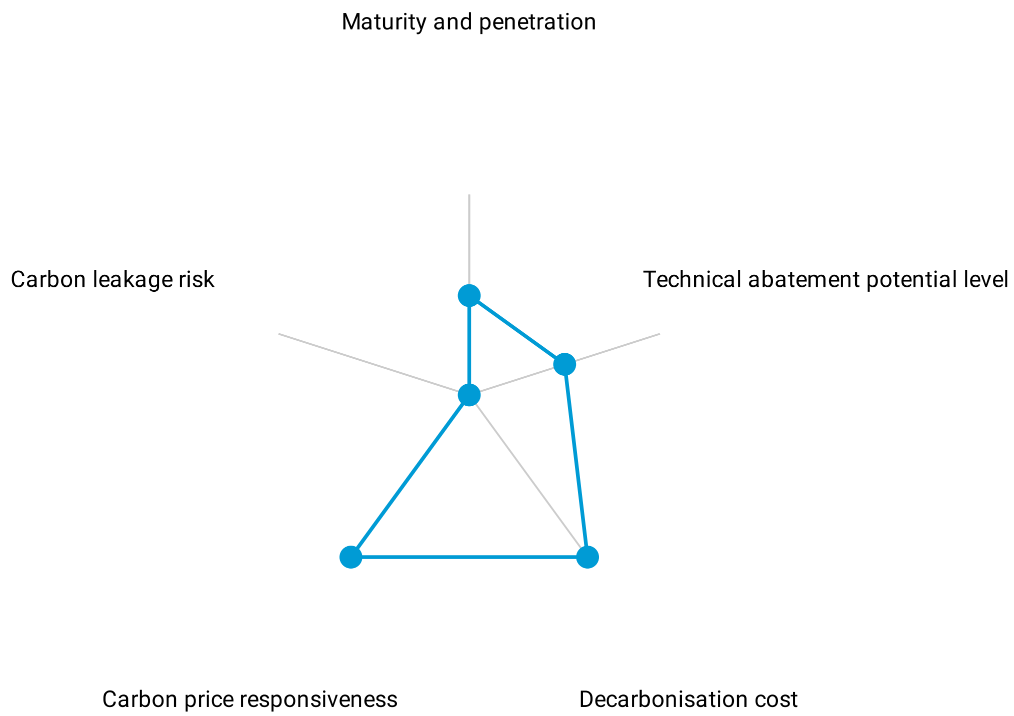
3.1.2 Heavy land-based transport

Table 10: Sector overview - heavy land-based transport

Heavy land-based transport	
Sector description	In this report, heavy land-based transport refers specifically to the trucking industry and its conveyance of goods. Globally, freight transportation – by truck, rail, ship or airplane – is responsible for 14% of total GHG emissions (Hammond et al, 2020). Road-based transport is responsible for more than half of all international trade-related emissions, demonstrating a targeted need to reduce emissions from heavy-duty road transport (International Transport Forum, 2019).
Context	The heavy land-based transport sector's capacity to abate varies by location and is dependent on a number of variables, including the quality of regulation, transparency in the market and fierceness of competition, and geographical size and existing land/train infrastructure.

Source: South Pole

Figure 9: Overview assessment of demand factors – heavy land-based transport



Source: South Pole

3.1.2.1 Technical: semi-optimal as technological abatement options are moderately mature for road transport but could be optimal if shifted to rail-based transport

The sector has the capacity to abate as technologies exist and are relatively available in the market. A review of the IEA's Clean Energy Technology Guide finds that many technologies to decarbonize heavy-duty trucks have been identified (IEA, 2020). These technologies include battery-electric trucks, hydrogen fuel-cell electric trucks and trucks powered by liquified or compressed biogas (IEA, 2020). All of the technologies score between a 7 (pre-commercial demonstration) and a 9 (commercial operation in relevant environment) (IEA, 2020) leading to the conclusion that the maturity and penetration of low-carbon technologies in the market in this sector can be classified as 'medium'. In other words, there are technical abatement options that the sector could use if the right policy incentives were in place to increase maturity and penetration. Another consideration is shifting the reliance on trains instead of heavy-duty trucks to transport cargo. While trains are technically mature technologies, they can lack geographical flexibility due to where the railway infrastructure is built. While railways can be built between major economic centres, it is unlikely that trucks will be fully replaced for 'last mile' delivery between the train depot and warehouses or retail stores.

The abatement potential of the mitigation options for heavy land-based road transport sector falls within the average of the sectors assessed (McKinsey & Company, 2009) leading to a rating of this sector's technical mitigation potential as 'moderate'. This mitigation potential for heavy land-based transport could increase if more freight was shifted to rail, though this depends on the geographical nature, and existing infrastructure, of the jurisdiction.

3.1.2.2 Economic: semi-optimal due to limited carbon price responsiveness, though this sector is not at risk of carbon leakage

While there is little price responsiveness, alternatives exist (which must be promoted by policy) and there is no carbon leakage risk. Although technologies exist, there is a financial limitation to their use, leaving sectoral players with little option other than to pay the carbon price. The main challenge heavy land-based transport faces in terms of decarbonization relates to the mitigation costs of technologies. While there are many proven options available to reduce the GHG emissions of heavy-duty trucks, such as improvements in aerodynamics and tire design, full decarbonisation of this industry would likely require a substitution of fossil-fuel-derived fuels like diesel with new liquid fuels or electric engines (ETC, 2018). Alternatively, trucks could be powered via overhead catenary lines on electric highways (Siemens, 2018); however, the construction of these lines is associated with high upfront infrastructure costs (Institute for Energy and Environmental Research & M-Five, 2018). Another alternative could be increasing reliance on transporting goods on electric rails; however, this would need to ensure the railway infrastructure is connected to where goods are imported and exported to the country, and the major economic centres. It would also require ensuring these rail-based transport has the capacity to accommodate the increased amount of cargo that was previously moved by trucks. The use of trucks is unlikely to be fully eliminated, as they would be required for last-mile transport between warehouse to end retailer or consumer. While there are some lower-cost options (like the increased use of bio-diesel options), most mitigation options will include more medium costs (like increasing electric vehicle (EV) fleets) to build out infrastructure to either accommodate electrified trucks or expand rail infrastructure.

Research has found that increased fuel costs, a likely outcome of a strengthened or new carbon pricing scheme, lead to a modest increase in demand for fuel-efficient trucks relative to their less-efficient counterparts (Resources for the Future, 2020). Indeed, researchers have found “that long-haul truck owners' willingness-to-pay for a 1% increase in fuel efficiency is, on average, just 29.8% of the expected future fuel savings” (Adenbaum et al, 2019) a probable indication that heavy-duty truck owners’ value features other than fuel efficiency in their fleet. Consequently, the carbon price responsiveness of this sector is deemed to be limited.

A review of the existing literature finds that the trucking sector is not the subject of concern as it relates to carbon leakage risks, as the trucks provide services to the local economy (Transport & Environment, 2013). As a result, its carbon leakage risk is classified as limited and the introduction of carbon offsets would not play a role avoiding leakage.

3.1.2.3 Design considerations

The role of offsets plays a variable role depending on the type of policy policymakers choose to adopt to decarbonize the sector. There are four main policy options relevant to heavy-land based transport. First, policymakers could impose technological standards in terms of fuel efficiency, increased biodiesel blending requirements or increased penetration rates of EV as part of companies' fleets. Second, policymakers could provide support policies to help with overcoming the technological challenges and economic costs that prevent mitigation from occurring. These could include low-carbon subsidies to help trucking companies with adopting low-carbon vehicles or more funding directed towards electric infrastructure for trucks and rail. This option could be part of COVID-19 recovery packages, given the reliance on heavy-based transport to move goods. Third, policymakers could impose carbon prices on energy consumed by heavy-based transport, either at the pump for transport fuels or carbon prices on electricity consumed by trucks and trains. Fourth, policymakers could adopt a programme similar to CORSIA for heavy-based transport requiring compliance actors to surrender offsets that exceed a certain sectoral target.

It is only for this third and fourth option that offsets could play a more prominent role as a cost-containment measure. For the third option, policymakers could allow offsets to be bundled as part of the consumption of transport fuels and electricity, but this is surrendered by the fuel/electricity provider. The fourth option would require the operators of the heavy-based transport fleets to surrender offsets if they pass a certain emissions threshold. These options can be more attractive to governments that are fiscally constrained, putting the cost burden on energy providers, or through a CORSIA-like programme on fleet operators – which could be a more feasible option. In either case, however, governments should ensure offsets are only used as an interim measure as the mitigation costs of low-carbon fleets decrease.

Tackling transport emissions is seen as a fundamental priority to achieving the targets set out by the Paris Agreement. While most of the focus is based on either light road transport or transport emissions from aviation and shipping, it is recognized that emissions from heavy-based transport also need to be addressed. So far, policies that aim to reduce emissions for this sector are largely not included in current NDCs and ETSs, though it is likely that this sector faces these costs indirectly through carbon prices being passed on through transport fuels or electricity.

3.2 Supply side

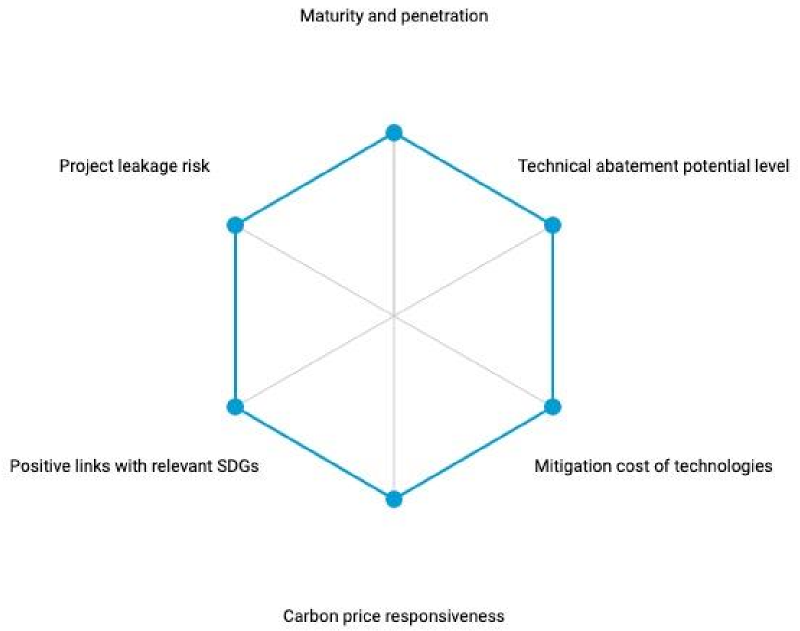
3.2.1 Household and community-based projects in LDCs

Table 11: Mitigation activity overview - household and community-based projects in LDCs

Household and community-based projects in LDCs	
Mitigation activity description	Household projects include all mitigation activities focused on reducing GHG emissions from homes, whereas community-based mitigation activities are those that implement activities that are of interest to the community itself and further sustainable development. Some examples of household and community-based projects include the distribution of water purifiers; water, sanitation, and hygiene (WASH) interventions in households; household waste management improvements; and the distribution of efficient cookstoves, efficient light bulbs, small-scale renewable energy systems (e.g. solar lanterns) and biogas digesters.
Context	The UN describes LDCs as those that exhibit the lowest levels of socioeconomic development**.** The capacities of households and communities to abate their GHG emissions is highly dependent on location. Developed countries are unlikely to need these kinds of projects, as centralized utility infrastructure provides for services such as electricity, water and sewage. However, in developing countries, where the vast majority of the world's poor live, the provision of such utility services is significantly more limited. Technologies for household and community-based projects generally have low market penetration in LDCs due to the limited financial capacity of local actors, preventing them from paying the upfront costs to implement these mitigation activities. Consequently, if policymakers (particularly those in developed country jurisdictions) wanted to support the deployment of these technologies by allowing household and community-based offsets to be eligible to be surrendered for compliance, policymakers should ensure that these projects are restricted to low-income countries only and LDCs in particular.

Source: South Pole

Figure 10: Overview assessment of supply factors – households and community-based projects in LDCs



Source: South Pole

3.2.1.1 Technical: optimal with the availability of mature technologies that can be deployed

Households and small communities around the world – and especially in LDCs – are the most vulnerable to the hazards presented by climate change. At the same time, utility services for cooking, electricity and water play a key role in the mitigation of GHG emissions (Rennaud et al., 2013). Examples of cooking technologies include solar cooking and liquid petroleum gas stoves. For light provision, solar lanterns are commercially available and have sufficient capacity to support the lighting needs for households where the weather allows. Moreover, households could even have their own batteries to store solar electricity at night. As battery costs tend to be high for individual households, households could connect their solar systems to a centralized battery to share the costs and even provide excess electricity to others. This type of project creates community-based microgrids by connecting households (BNEF, 2019). Low-carbon technologies for cooking and electricity reduce emissions from the burning of kerosene for small cooking units and lanterns, diesel for generators or cow dung for cooking. Poor households can also be highly reliant on cutting down trees to meet their cooking, electricity and heating needs. WASH technologies include clean water filters and waste treatment technologies such as biodigesters. These can be used for household sewage or even for animal farms where emissions from manure are released. WASH technologies reduce methane emissions.

According to the IEA's Clean Energy Technology Guide, the clean-energy technologies classified as belonging to the 'cooking' subsector are, by and large, either commercially available (TRL 9) or commercial and competitive but in need of further integration efforts (TRL 10) (IEA, 2020). Other household technologies such as small-scale solar-based systems and WASH technologies are also mature, and battery technologies for household and community capacity needs are becoming more mature and cost efficient.

Consequently, the household and community-based projects apply mature technologies whose potential to reduce emissions significantly can be achieved if they reach high penetration in LDCs.

3.2.1.2 Economic: optimal

In general, household and community-based projects are inexpensive but economic limitations for actors in LDCs exist. A review of the existing literature reveals that household and community-based projects are quite inexpensive. For example, some clean cookstoves cost less than USD 100 and are associated with high volumes of carbon savings (Cundale et al, 2017). In addition, the responsiveness to carbon prices is high, due to low incomes among the populations targeted by offset projects in the sector.

3.2.1.3 Environmental and social: optimal as there are a great number of potential environmental and social impacts beyond the mitigation outcome

Household and community-based projects are associated with a broad range of potential co-benefits that are very interconnected. WASH and clean cookstoves can improve good health and wellbeing (SDG 3) by providing clean water and sanitation (SDG 6) and reducing air pollution that is the cause of respiratory diseases (particularly from cooking with firewood or cow dung). The burning of this kind of biomass also contributes to 'Life on Land' (SDG 15) by reducing air pollution and deforestation caused by firewood harvesting, thereby also achieving SDG 12 on responsible consumption.

There are also specific SDGs that can support poverty reduction (SDG 1). Small-scale renewable electricity systems and cookstoves provide affordable and clean energy (SDG 7) that can help achieve universal access to energy for remote populations that are the most difficult to connect to the grid. Projects that replace kerosene lamps with solar ones curb household expenditure on energy, contributing to a reduction in energy poverty. These projects also promote gender equality (SDG 5), as a disproportionate number of women – and importantly, girls – who typically spend a significant portion of their day collecting water or firewood can redirect this time towards school and studying. The provision of electricity to schools and households can also improve the quality of education (SDG 4) by powering devices that can provide access to online learning resources. Offset projects that support training capacity to build these technologies (e.g. small-scale solar systems) can also provide employment opportunities to support SDG 8 on decent work and economic growth. Unlike some other carbon offset project types, household and community-based projects are not associated with a high risk of negative impacts. Consequently, the potential for this sector to achieve multiple SDGs is classified as 'high'.

3.2.1.4 Design considerations

Despite most household and community-based mitigation activities being commercially viable and available on the market in most countries, their use in LDCs is limited by local actors' lack of technical and financial capacity. Hence, policymakers should ensure that offsets are only allowed to be sourced from projects that target actors with limited abatement capacities.

However, policymakers should be aware of the rapidly changing market and policy scenarios that could challenge the additionality of these mitigation activities. First, policymakers can provide technology subsidies to actors that would help with the deployment of these mitigation activities. Second, there is an increasing number of businesses that are providing financing models that can help actors pay the upfront capital costs for these systems through microfinance or 'leasing' arrangements. If these alternative financing models have a great penetration in LDCs, the additionality of these household and community-based projects is challenged from a commercial perspective. In the absence of these developments, using the offset mechanism to support the deployment of these mitigation activities to meet the utility needs for households and communities in LDCs would contribute to emissions mitigation and the realisation of SDGs.

3.2.2 Large-scale renewable energy generation and smart systems in LDCs

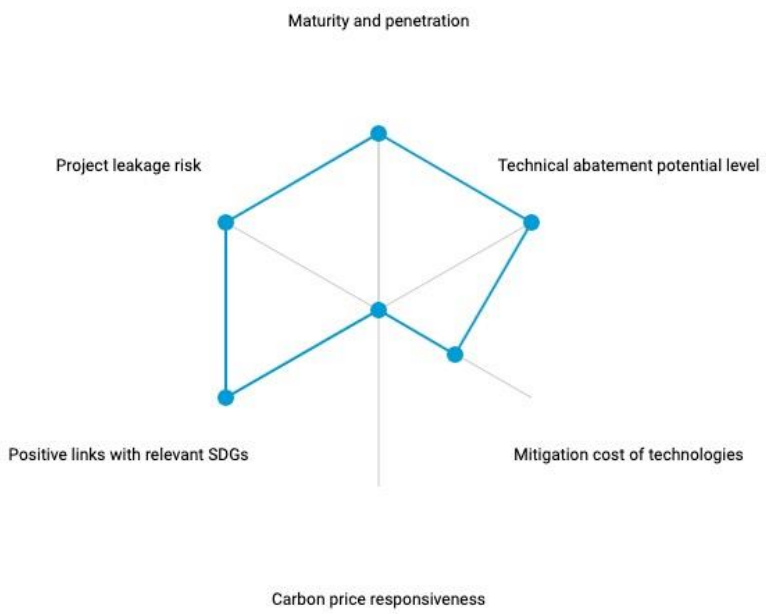
Table 12: Mitigation activity overview - large-scale renewable energy generation and smart infrastructure in LDCs

Large-scale renewable energy generation and smart infrastructure in LDCs	
Mitigation activity description	The power sector is undergoing revolutionary changes with the integration of telecommunications infrastructure with power infrastructure to support a 'smart' system. Smart systems refer to technologies and infrastructure that balance the supply and demand of energy between producers, consumers, and balancing capacity (e.g. energy storage) to "smooth" out the imbalances by sending signals to each entity. This smart system is needed as more large-scale and small-scale producers of renewable energy are connected to the grid, which can destabilize the grid infrastructure if supply and demand are not well matched due to variable renewable electricity generation. This imbalance can also occur with greater demand from fast-charging infrastructure for EVs. Several technologies, including in the areas of batteries, energy efficiency, smart meters and appliances (which can respond to real-time signals to more efficiently managed energy use), are being integrated across parts of the power system to better balance this variability. Telecommunications infrastructure is also being overlaid onto power infrastructure to provide more real-time signalling. This provides a more dynamic and real-time balancing of the system to make it 'smart' and allows for greater penetration of variable renewable energy and management of EV charging.
Context	Public support policies for the deployment of large-scale renewables and smart systems are occurring in many developed and emerging economies as they invest in upgrading and decarbonising their power sector. In most countries, large-scale renewables such as solar and wind technologies are also becoming more commercially viable. While it is unlikely that large-scale renewable energy and smart systems are considered to be additional to existing policy-support and financial mechanisms, it is also unlikely that LDCs will have the fiscal budget needed to decarbonize their power sector through these technologies. In the context of LDCs, these kinds of mitigation activities would be considered financially additional when there is a lack of fiscal or private financing sources. Furthermore, there are significant urban populations living in slums in LDCs that do not have access to electricity provided by the grid. Even populations connected to the grid are likely to receive poor quality electricity service that is prone to blackouts due to insufficient power capacity. These mitigation options do not have large penetration in LDC markets due to limited access to these technologies and limited technical capabilities to develop such projects (including limited

Large-scale renewable energy generation and smart infrastructure in LDCs	
	urban planning capacity). Therefore, these activities are technically optimal for mitigation in LDCs, as they use mature technologies that can reduce power sector emissions in the LDCs but have not achieved significant penetration rates. Consequently, offset projects involved with large-scale renewable energy generation and/or smart infrastructure investments will most likely be additional in the absence of domestic or international financial support. As these projects can be transformative for the LDC power markets (in terms of helping LDC power markets move directly to a more sophisticated and low-carbon power system rather than being locked-into a more carbon-intensive infrastructure), policymakers outside of these countries can choose to allow offsets from these projects to be eligible for domestic compliance to channel carbon finance to these projects.

Source: South Pole

Figure 11: Overview assessment of supply factors – large-scale renewable energy generation and smart infrastructure in LDCs



Source: South Pole

3.2.2.1 Technical: optimal to semi-optimal

Large-scale solar and onshore wind generation are more mature technologies, with certain technologies for smart systems (such as smart metering and battery storage) reaching commercial maturity that could enable abatement for LDCs' power sectors (IEA, 2020a). Renewable energy generation that is connected to smart systems provides LDCs with the large technical abatement potential to decarbonize their existing power sector and prevent the addition of capacity that is locked into carbon-intensive sources. To provide universal access to high quality electricity, LDCs that have insufficient power generation capacity or infrastructure to achieve this goal within their countries will need to invest in building out additional power capacity and infrastructure (UN, n.d.).

The traditional model for providing electricity to urban populations is through centralized, large-scale fossil fuel generation that requires building large-scale transmission and distribution infrastructure. Industrial sites can be connected to central grids, while also having onsite generation through carbon-intensive sources, such as coal or diesel. LDCs are at risk of increasing future power sector emissions if they were to consider increasing their power capacity using fossil fuel generation. This emissions trajectory would be exacerbated if these countries economically develop to consume more electricity, either through increased industrialisation or a rise in energy demand associated with more affluence.

Interestingly, LDCs have the potential to escape this model of fossil-fuel intensive development, particularly as it may be less suitable for the LDC context. First, most LDCs are in regions that have favourable conditions for the large-scale generation of renewable energy (Energy Data, n.d.). For concentrated populations in urban and industrial areas, large-scale renewable electricity generation that is connected to smart infrastructure can better balance the supply and demand of electricity. This power sector model can replace existing capacity that relies on fossil fuels to reduce emissions. Policymakers could also consider how future emissions would be avoided if additional power capacity was met using renewable energy and smart infrastructure rather than fossil fuels. It would be important to present the technical mitigation options for large-scale renewable energy generation to LDC governments to avoid the carbon-intensive lock-in of future capacity.

Therefore, large-scale renewable energy generation that is balanced using smart systems that are more commercially viable in the global market, such as smart meters and energy storage (particularly battery technologies), could further support the mitigation potential of the power sector in LDCs. These technologies are most likely to have limited penetration in these markets, even though they are commercially viable from a global standpoint.

3.2.2.2 Economic: optimal and semi-optimal

The high upfront mitigation costs of these type of mitigation activities are decreasing but can still be high for LDCs; carbon price responsiveness is low in LDCs contexts. The investments in large-scale renewable energy and smart systems have high upfront costs and are capital-intensive, but it’s payback is recouped by having lower reliance on fossil fuels (IRENA, 2019a). The costs of large-scale renewable energy systems such as solar and onshore wind technologies have become competitive with fossil fuel technologies (IRENA, 2019a). The costs of certain smart technologies, such as smart meters and battery technologies, are also decreasing as the global capacity to manufacture these technologies scales (IRENA, 2019b).

Therefore, at a global level, mature renewable energy technologies and certain smart technologies are commercially viable to support deployment if governments, or electricity utility companies, can finance the upfront costs of installing these technologies and the associated infrastructure. In most countries, electricity grid infrastructure is funded through the fiscal budget and is managed by a centralized monopoly to recover the long-term costs. While building renewable energy generation and smart infrastructure takes time, governments could be ‘carbon price responsive in the long run’ by moving to electricity generation that relies more on renewables than fossil fuels, as this frees up fiscal capacity that would otherwise be used for fossil fuel subsidies to reduce costs to consumers.

LDCs are unlikely to have the fiscal budgets needed to upgrade and extend the existing infrastructure. Furthermore, while LDCs could technically pass on the costs of building such power capacity and infrastructure to their consumers, it is unlikely that these consumers will be able to afford to do so through their electricity bills. The power sectors in LDCs are known for being undercapitalized due to the inability of electricity consumers to pay the real price of electricity, which explains why in many countries (not just LDCs) the electricity price is subsidized. It is therefore unlikely that LDCs can be carbon price responsive due to limited fiscal capabilities or consumer constraints.

Therefore, the use of the offset mechanism to finance large scale renewable generation deployment and smart infrastructure is optimal as the technologies themselves are commercially viable from a global standpoint but financially additional in the context of LDCs. The upfront capital costs make this option less carbon price responsive, and therefore, a high compliance price would be needed to enable the offset mechanism to work in the LDC context. It is unlikely that LDC governments would impose this kind of compliance price signal; however, countries looking to source Article 6 projects may be more willing to pay a higher price to support emission reductions.

3.2.2.3 Environmental and social: optimal

Due to the lack of universal access to electricity in LDCs, these type of mitigation activities, which provide such access, achieve SDG 7 (affordable and clean energy). This kind of power capacity and infrastructure build out achieves SDG 9 by improving industry, innovation and infrastructure, as well as SDG 11 (sustainable cities and communities). Like the previous subsection on household and community projects, providing electricity to unconnected populations can also achieve many of the SDG goals associated with reductions in poverty, particularly with regards to providing quality education, gender equality, and good health and wellbeing. Therefore, the provision of affordable and clean electricity to poor populations does have the potential for realising several co-benefits.

There are currently no certified carbon projects for smart grid systems. It is not anticipated that there would be high risk of negative impacts to communities and the environment in building out smart grids. However, like all infrastructure projects, environmental impact assessments would need to be done to identify and measure the size of environmental impacts from the build out of power generation and infrastructure. As per the requirements of robust carbon standards, project developers would need to engage with local stakeholders in terms of assessing the viability and social impacts of the projects, along with working them in the implementation and operation of such projects. It would be important to have robust MRV systems in place that can minimize and address any negative impacts that could occur.

3.2.2.4 Design considerations

High potential for contributing to SDGs beyond the mitigation activity outcomes in LDCs. Though large-scale renewable energy generation is commercially viable in most contexts, it is considered to be additional in the LDC context due to the high mitigation costs and low technical capacity. In fact, crediting mechanisms such as Gold Standard and the Verified Carbon Standard only certify large-scale generation in LDCs as these mitigation activities are considered to still be additional in these contexts (Hiterski, 2020). The additional sources of finance from the sale of offset revenues can recoup investments resulting from the high upfront investments, and therefore, play an important role in mitigating emissions in LDCs' power sectors. However, as the international community, including multilateral development banks and the private sector, recognize the urgency to address poverty in LDCs, these kinds of projects are increasingly attractive from a financial aid perspective (LDC REEI, n.d).

It is more likely that policymakers outside of LDCs would like to use the carbon finance mechanism to finance these mitigation activities in LDCs. Such financing can support the low-carbon development of power systems in LDCs. Therefore, policymakers outside of LDCs could make offsets from mitigation activities in the LDCs eligible for their domestic compliance scheme. However these policymakers should keep track of other sources of international climate finance that could be used to support the deployment of these mitigation activities, thereby jeopardising their financial additionality. These additional sources of finance can determine whether these mitigation activities can be certified to supply offsets under the additionality requirements of carbon standards.

Policymakers that are from LDCs and those outside of LDCs need to work together to assess whether additional mechanisms need to be put in place to ensure the successful implementation of these types of technologies in the LDC context. Technical capacity is particularly needed for designing power capacity generation and infrastructure to support LDCs' needs (LDC REEI, n.d). This challenge becomes difficult if LDCs experience rapid urbanisation, as this makes the development of optimal power infrastructure more difficult from a planning perspective. In many cases, poor populations move to cities that have limited affordable housing, which can often result in the development of slums that further complicate the design of effective power infrastructure.

On-the-ground capacity also needs to be built when pairing large-scale renewable energy generation with smart systems to enable balancing supply and demand across the system. This technical capacity needs to target system operators, who need to know how to use the software behind the smart system to monitor whether the different systems balancers (either through sending signals to smart meters or the use of energy storage) is working appropriately and address any issues that could disrupt the functioning of the system.

3.2.3 Combined heat, power and cooling (aka trigeneration) for heavy industry, district heating and buildings

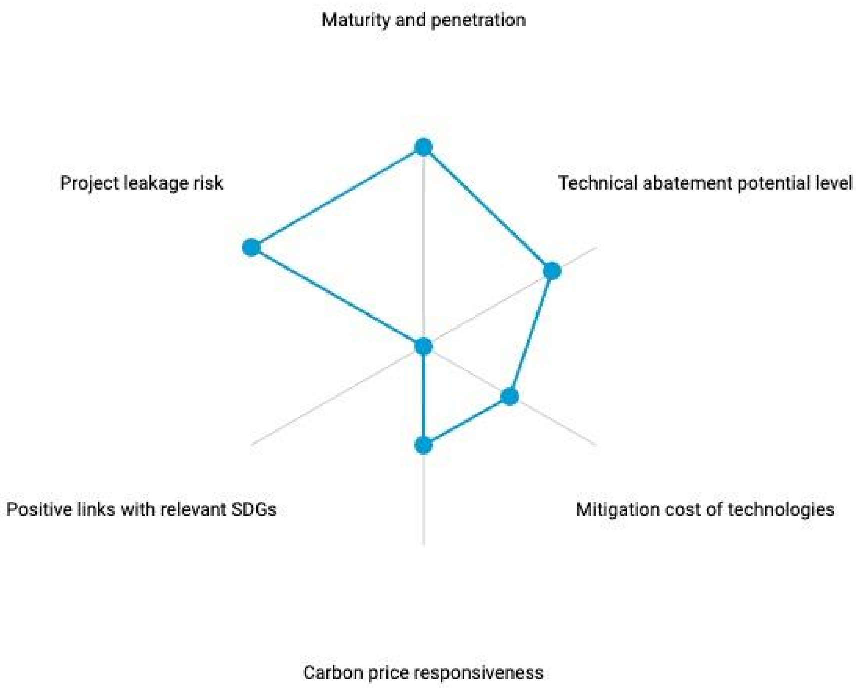
Table 13: Mitigation activity overview - combined heat, power and cooling (aka trigeneration) for heavy industry, district heating and buildings

Combined heat, power and cooling (aka trigeneration) for heavy industry, district heating and buildings	
Mitigation activity description	Combined heat and power (CHP, more recently referred to as trigeneration technologies when it includes cooling) consists of capturing waste heat from electricity generation or industrial processes and running it into an integrated system that can generate more electricity while providing heating and/or cooling for the industrial facility. CHP improves energy efficiency by creating an integrated process rather than having two or three different systems (each requiring its own energy source) to provide electricity, heating and cooling. As such, it lowers emissions by reducing the amount of energy needed by an industrial facility for district heating or buildings.
Context	There are a variety of CHP technologies at different stages of maturity. Certain countries are also more advanced in terms of increasing the penetration rates

Combined heat, power and cooling (aka trigeneration) for heavy industry, district heating and buildings	
	of more mature CHP technologies than others, including putting deployment targets. Therefore, it is very important for policymakers to develop sectoral baselines (based on technological penetration rates, commercial viability and policy mandates) that determine whether a specific CHP technology has reached the penetration rate that signals it worthy of consideration in such baselines, rather than as a suitable offset.

Source: South Pole

Figure 12: Overview assessment of supply factors – combined heat, power and cooling (aka trigeneration) for heavy industry, district heating and buildings



Source: South Pole

3.2.3.1 Technical: semi-optimal or optimal, depending on the type of CHP technology

CHP has the potential to reduce emissions by improving energy efficiency – its penetration rates could be low for industrial facilities or buildings depending on the country and technology type. CHP technology involves converting chemical fuel into electric power. The different types of technologies include reciprocating engines, steam turbines, gas turbines, micro-turbines and fuel cells. The first four types of technologies are classified as heat engines, as they require the combustion of fuel to produce heat that can then be used to generate electricity and enable heating/cooling. Fuel cells, on the other hand, directly convert the energy in a fuel source into electricity. The size of mitigation, however, is dependent on the amount of emissions that would otherwise be released from the separate systems of providing onsite electricity, heating (through separate boilers) and cooling (through heat exchanges, air conditioning or refrigerant technologies). As each of these technologies is very energy intensive, creating a combined and integrated system improves the energy efficiency of industrial facilities and buildings. Depending on the type of CHP technology used (IEA, 2017) this can increase overall efficiency to 65-80%, which is much higher than the average efficiency of natural gas or coal power generation technologies, that lie at 22 to 40%.

The mitigation potential is also dependent on the carbon intensity of the original fuel source and the uses of thermal output. CHP technology involves converting chemical fuel into electric power. CHP does not necessarily change the original fuel source that is used at the facility level, but instead reduces emissions by requiring less consumption of carbon-intensive fuel due to the increased energy efficiency. Industry facilities or buildings can consider switching the input source into less carbon-intensive fuels, such as hydrogen (using fuel cell technology) or power generated from renewable sources, to further reduce emissions.

Most of the CHP technologies (apart from fuel cells) are commercially viable but the penetration rates can be low for industry and buildings depending on the country and the type of CHP technology. Therefore, it is very important to perform a sectoral assessment to understand the penetration rates of different CHP technologies and to determine the potential for further mitigation in industries and buildings. Given the increased energy efficiencies that these technologies have the potential to produce, they are optimal in terms of carbon savings. Table 14 below, shows the types of CHP technologies that could be relevant to industrial and building applications.

Table 14: CHP technologies and markets

	Industrial CHP	District heating and cooling	Commercial and residential
Typical users	Chemical, refinery, iron and steel, glass, coking	Private and public buildings	Light manufacturing services, buildings, agriculture
Temperature level	High	Low/medium	Low/medium
Size (MWe)	2 - 500	10 - 250	0.001 - 10
Prime mover	Steam and natural gas turbines, ICEs, CCGT	Steam and natural gas turbines, CCGT, waste incinerators	ICEs, fuel cells, Stirling engine, microturbines
Energy source/fuel	Liquid, gaseous or solid fuels, industrial waste gas	Liquid, gaseous or solid fuels, industrial waste gas	Liquid or gaseous fuels

Source: South Pole based on IEA, 2008; Lako and Tosato, 2010

3.2.3.2 Economic: optimal, semi-optimal or sub-optimal depending on CHP technology

The costs of CHP can vary substantially from country to country depending on construction resources, input prices of fuels used, the energy demand for industry and buildings (which determines the size of the CHP plants needed), and most importantly, the type of CHP technology. Table 15, below, provides a summary of the costs associated with different CHP technologies.

Table 15: Costs of different CHP technologies

CHP technology	Investment costs	Annual operation and maintenance costs
Gas-turbine CHP	$900/kW_e to $1,500/kW_e (average cost of $1,000/kW_e)	$40/kW_e
Combined-cycle (CCGT) CHP	$1,100/kWe to $1,800/kWe (average cost of $1,300/kWe)	$50/kW_e
Gas-engine CHP	$850/kW_e to 1,950/kW_e (average cost of $1,150/kW_e)	$250/kW_e

Source: IEA, 2010

As the country's contextual factors are important in determining costs, it would be important to determine whether the costs of CHP plants could be financed through commercial means or would require an extra stream of investments. Most CHP technologies are considered to be medium costs (optimal) except for fuel cells, which are still too expensive. Therefore, fuel cell technologies are considered to be sub-optimal.

The carbon price responsiveness is also based on the type of CHP technologies. In some cases, the upfront costs are high as they essentially are the building of new facilities, while other types of CHP technologies can be retrofitted to existing facilities to make them more efficient. Carbon leakage is low as these types of technologies would not interrupt the activity in the sectors where they get applied.

3.2.3.3 Environmental and social: low

Mitigation activities involving CHP technologies do not contribute to additional environmental and social benefits beyond SDG 9 (improving industry, innovation and infrastructure). Environmental and social impact assessments, along with strong MRV systems, should be done to identify and mitigate any potential negative risks that could result of construction and operation of these technologies.

3.2.3.4 Design considerations

As CHP technologies can rely on thermal input sources like coal, it would be important for policymakers interested in supporting CHP deployment (either domestically or in other jurisdictions) through making these projects eligible for offset supply to have specific restrictions to prevent supporting CHP projects that lock-in coal consumption for industry and buildings. Policymakers could exclude CHP that consume coal to supply offsets, while allow CHP that are powered from low-carbon sources.

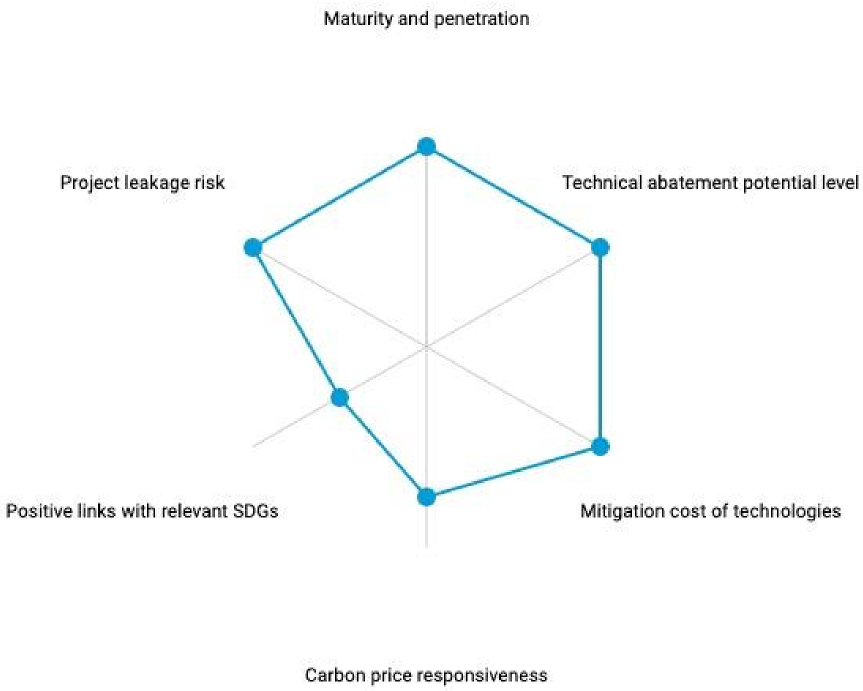
3.2.4 Electric arc furnaces for iron and steel

Table 16: Mitigation activity overview - electric arc furnaces for iron and steel

Electric arc furnaces for iron and steel	
Mitigation activity description	The iron and steel sector are the largest source of CO_2 emissions from the industrial sector, and the second-largest consumer of energy (IEA, 2010). Steel is the final product derived from a process of extracting iron from iron ore through a heat-intensive process and then blasting it with oxygen, a process known as coke oven-blast furnace-basic oxygen furnace (CO-BF-BOF).

Electric arc furnaces for iron and steel	
	Electric arc furnaces (EAF) provide an alternative production method that uses electricity to melt scrap steel so it can be re-used. As an overall process, EAF is less emission-intensive than CO-BF-BOF because it bypasses the process of extracting iron ore and can have electricity sourced from renewable energy. Aside from CCUS (please see mitigation activity profile on CCUS for heavy industry), EAF are recognized as the mitigation option of choice for reducing the emissions of the iron and steel industry.
Context	There are two key contextual variables to determine whether EAF should be considered for offsets supply. The first is whether the jurisdiction has supply chains that can gather enough scrap steel to be used in EAF facilities. Second, EAF tends to have high penetration in countries that do have these supply chains in place, and therefore, EAF should be considered as part of the sectoral baseline rather than counting as additional carbon credits.

Figure 13: Overview assessment of supply factors - electric arc furnaces for iron and steel



Source: South Pole

3.2.4.1 Technical: optimal

EAF are a commercially mature technology with high technological potential to reduce emissions from iron and steel production but with low penetration rates in many countries. The oldest production method and incumbent technology for producing produce steel is through a coke oven-blast furnace-basic oxygen furnace (CO-BF-BOF), accounting for 70% of the global production of iron and steel. EAF is a technology that has the technical potential to reduce emissions from the incumbent CO-BF-BOF technology in the following ways. First, EAF that uses scrap metal is less energy-intensive than BOF as it does not need to undergo the step of extracting iron from iron ore. This can lead to EAF using 64% less energy than CO-BF-BOF per tonne of crude steel (IEA, 2017: 187; World Steel, 2017). Second, it has the potential to further reduce emissions if it relies on renewable electricity, while CO-BF-BOF uses coke to heat its furnaces. Consequently, iron and steel facilities that change to EAF, which themselves rely on low-carbon electricity, can reduce their emissions. EAF can also play an important role in balancing electricity grids with high renewable electricity penetration by running the EAF when the spot electricity price drops due to high renewable energy generation.

Another advantage of EAF is that it is a commercially mature technology, but globally, only accounts for 30% of steel production. This varies by country, as it is dependent on supply chains that are able to salvage scrap metal versus those countries that have low-quality indigenous coal and iron. For example, EAF accounts for 60% of steel production in the United States (US) due to programmes that recycle steel but is unlikely to have high penetration in countries like China and India (IEA, 2017). Therefore, there should be careful consideration of whether EAF qualifies on additionality grounds by geography, based on its penetration. EAF is also more attractive from a mitigation perspective when the infrastructure is in place to collect scrap metal to be used in EAF facilities.

3.2.4.2 Economic: optimal and semi-optimal (based on the availability of scrap metal)

Mitigation costs of EAF are based on multiple factors, but costs could be high enough to be financially additional and benefit from carbon pricing revenues if the carbon price itself is high. There are three major ways that EAF can pose high mitigation costs for the iron and steel sector. First are the costs of refurbishing existing CO-BF-BOF plants, which would represent significant costs as these plants are much larger than conventional EAF plants (which are considered to be mini-mills in comparison). While the conversion of CO-BF-BOF plants to EAF plants will improve their energy efficiency and reduce their reliance on coke, the costs of the refurbishment will be extensive. Carbon financing could therefore be used to pay for the capital costs of refurbishment if the carbon price is high enough.

The second option is to build new EAF plants rather than new CO-BF-BOF plants. While new EAF plants are less expensive to build due to their smaller size, they could be exposed to higher operational costs depending on a given country's electricity prices and scrap metal acquisition costs. The costs of buying scrap metal could be high due to its limited availability or immature supply chains. If these operational costs are high enough to prove financial additionality of the new EAF plant, carbon financing could be used to cover these costs. The carbon price responsiveness for refurbishments could occur, but offset suppliers are unlikely to responsive for building new EAF plants due to the upfront capital costs.

It should be noted that the crediting periods for these projects could be shorter to monitor whether electricity prices and improvements in supply chains reduce the input costs for these projects, thereby proving they are no longer financially additional. Lastly, the mitigation costs could be high if EAF plants increased their reliance on buying renewable electricity through corporate procurement contracts or building onsite renewable electricity capacity. The additional costs of the renewable energy contracts and/or onsite renewable plants – along with the underlying carbon price – could determine the financial additionality of the EAF plant and indicate whether the carbon price would be high enough to cover these costs.

3.2.4.3 Environmental and social: semi-optimal

The increased reliance of EAF on scrap metal could contribute to SDGs 9, 12 and 15, though it could also lead to job losses at CO-BF-BOF plants. First, it helps achieve SDG 12 (responsible consumption and production) by developing supply chains that create a demand to salvage scrap metal, particularly from municipal solid waste areas. By reducing the amount of scrap metal that is sent to landfill, it also contributes to SDG 15 (life on land). Third, EAF requires further industrial innovation to improve the quality of steel it produces. Unfortunately, EAF's current reliance on scrap metal leads to it producing a lower grade quality of steel than that produced by CO-BF-BOF – another key reason as to why BOF continues to be used (IEA, 2017). However using the process of the direct reduction of iron ore and integrating it to the EAF process can enhance quality of final steel product. It should be noted though this integrated process will increase the energy intensity of the whole process due to the first step of using direct reduced iron (DRI) – and therefore, it is important to ensure that EAF uses renewable electricity to ensure it reduces emissions in comparison to the CO-BF-BOF process. Further innovations that can improve the quality of the steel can increase uptake of EAF technologies. These innovations would support achieving SDG 9 on "Industry, innovation and infrastructure".

However, one potential downside if CO-BF-BOF plants are converted to EAF plants, is that it could lead to job losses from cutting out the production process that relies on extracting iron ore and converting it into steel. It is unlikely that the labour force involved in this part of the production process would be willing or able to transition into the jobs needed to support the salvaging of scrap metal, largely due to geographic variables (as it would require greater dispersion from the iron and steel mill) and the reduced number of jobs available in the latter process.

3.2.4.4 Design considerations

Policymakers may be willing to undertake industrial policies in terms of creating the supply chains and the financing of constructing new EAF facilities, or converting CO-BF-BOF to EAF, as a more direct way to deploy EAF rather than incentivising finance through the offset mechanism. However, governments would need to ensure they have the funds to provide such financing. Policymakers can also introduce technological regulations, such as carbon intensity standards for steele products, that favour EAF deployment. In this case, the financing burden shifts to the iron and steele facilities – whose owners may not have the financing to comply to this regulation. Therefore, policymakers could be interested in using the offset mechanism to encourage financing for EAF projects without making these requirements mandatory. The offset mechanism also provides a business model where third-party investors can provide the financing for EAF deployment to iron and steel facilities, and recoup the investments through the sale of credits.

There are two key design considerations that policymakers should consider when determining whether mitigation activities using EAF technologies are suitable to supply offsets. First, policymakers and crediting mechanisms should determine the level of penetration of EAF technologies in a country's iron and steel industry to determine whether it can be considered additional from a technological baseline. Second, policymakers should assess whether the appropriate supply chains exist to gather scrap steel metal that can be recycled for EAF. Without this supply chain, EAF could have limited mitigation impact for the iron and steel sector, and therefore, is unlikely to be suitable as an offset mechanism.

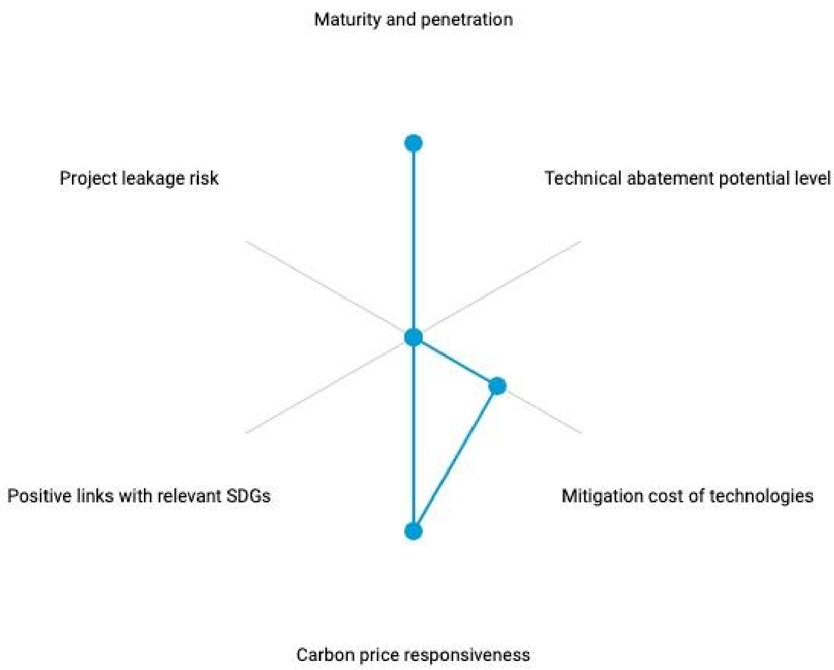
3.2.5 Methane mitigation options for the oil and gas industry

Table 17: Mitigation activity overview – Methane mitigation options for the oil and gas industry

Methane mitigation options for the oil and gas industry	
Mitigation activity description	There are three broad categories of technologies and processes to mitigate methane emissions from oil and gas production: (1) replacement of existing devices (such as valves, and gas-driven pneumatic controllers and pumps) to improve efficiencies; (2) installing new emissions control devices that reduce or avoid large sources of vented emissions (such as vapour recovery units and flare reduction technologies); and (3) leak detection and repair processes that help in locating and repairing fugitive leaks in production sites and connected infrastructure used to transport oil and gas.
Context	Methane emissions from the production and distribution of oil and gas account for about 21% of methane emissions released from anthropogenic activity in 2020 (IEA, 2021). McKinsey & Company (2020a) estimate that 62% of emissions from the oil and gas sector involve release of fugitive methane emissions and flaring of emissions. Therefore mitigating methane emissions from oil and gas production will be important in reducing global emissions. The IEA (2021) estimates that 70% of methane emissions from the oil and gas sector can be mitigated. Between 10 to 50% of methane missions can be reduced at no net cost, depending on the price of natural gas. The main component of natural gas is methane, therefore selling surplus natural gas by capturing methane emissions can payback the costs of installing new devices and repairing infrastructure. Offsets could play a role in supporting methane reduction for those options that would not be able to economically recover its costs through the sale of natural gas.

Source: South Pole

Figure 14: Overview assessment of supply factors – mitigating methane from oil and gas production



Source: South Pole

3.2.5.1 Technical: optimal with regards to abatement potential, maturity of technologies, and penetration of specific mitigation options

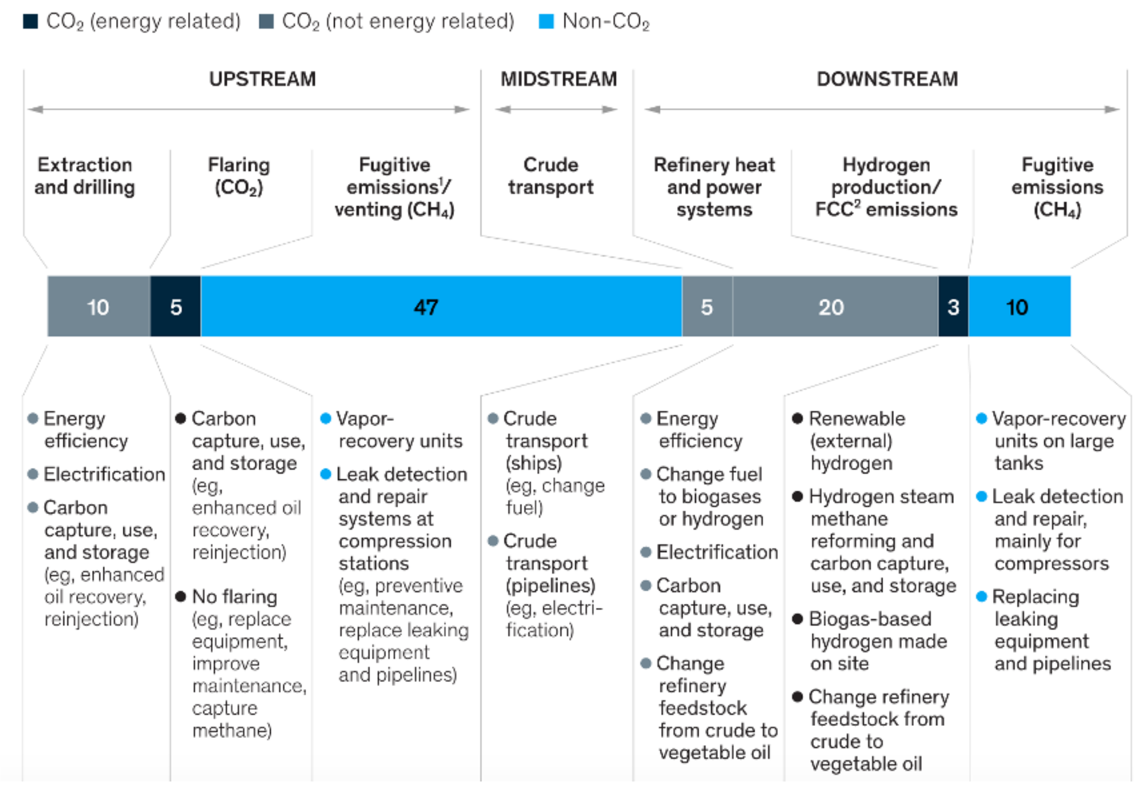
The IEA (2021) estimates that 70% of methane emissions from oil and gas production could technically be abated, leading to over 1,400 million tonnes of CO_2 equivalent emissions that could be reduced each year. Mitigation options for methane can broadly be classified into the following categories. The first is the replacement of existing devices to improve efficiencies, such as valves, and gas-driven pneumatic controllers and pumps. The second is installing new emissions control devices that reduce or avoid large sources of vented emissions, such as vapour recovery units, and technologies and processes that reduce the practice of flaring. The third is leak detection and repair processes that help in locating and repairing fugitive emissions. Figure 15 below shows that mitigation activities that address methane (represented as CH_4) emissions could address about 62% of emissions from oil and gas production and distribution (McKinsey & Company, 2020a).

Despite the significant technical abatement potential and maturity of technologies, the IEA (2021) notes that the penetration of these technologies has been limited for the following reasons. First was a lack of data and monitoring systems in facilities to estimate the size of methane emissions that were being leaked. Oil and gas operators also lacked awareness on the potential cost-effectiveness from using captured methane to boost sales of natural gas to markets. Methane emissions have historically been difficult to monitor, though improvements in satellite data and on-the-ground methane detection devices (such as infrared cameras) are being used to identify where methane is leaked. Leak detection and repair processes are easier to conduct at production sites and more difficult to detect in pipeline infrastructure.

The second challenge are economic, regulatory, or technical barriers that prevent the delivery of natural gas to markets (World Bank, 2021). This challenge is particular to incentivising oil and gas operators to reduce the practice of flaring methane emissions. Flaring released 400 million tonnes of CO2 equivalent in 2020, with 65% of global flaring occurring in Russia, Iraq, Iran, the United States, Algeria, Venezuela, and Nigeria (World Bank, 2021). To avoid flaring, equipment maintenance needs to be carried out to avoid equipment failures. Flare recovery systems capture methane emissions, which are recycled back into the production facility for export to markets. However, if markets cannot absorb this boosted supply of natural gas, oil and gas operators can do the following actions. Operators can stop or reduce onsite production, so that natural gas supply balances with market demand. This option is more available for sites that produce natural gas only. However, oil operators are more likely to flare the natural gas so that oil production can continue. Therefore in order to stop the practice of flaring, it is important to have markets that are able to absorb increased supplies of natural gas that are caused by reduced flaring. It is important to have sufficient pipeline capacity that can transport increased supply of natural gas to market.

Offsets could play a role in increasing the penetration of methane mitigation technologies that are less capital intensive, such as replacing existing devices, and repairing leaky pipeline infrastructure. Offsets can also support implementation of flare reduction systems, however the reliance on sufficient pipeline infrastructure and markets could inhibit this potential.

Figure 16 Mitigation options for producing, refining and distributing oil and gas



Source: McKinsey & Company, 2020a. *Note: numbers shown in the bars are the percentage of each activity level's emissions to total oil and gas emissions. [1]Fugitive emissions from mid-stream are included in upstream. [2]Fluid catalytic converters

3.2.5.2 Economic: optimal and sub-optimal depending on natural gas price

The IEA (2021) estimates that 10 to 50% of methane emissions that could technically be abated could do so at net cost, depending on prices for natural gas markets. The capture and sale of methane that would otherwise be released into the atmosphere could recover total financial costs of implementing these mitigation technologies and process systems. Even the construction of new pipeline infrastructure could recover costs of increased natural gas that is transported to markets.

Offsets would be suitable for those projects that could not recover their costs from the increased sale of natural gas. Unlike oil markets, natural gas markets are geographically constrained as most natural gas is transported through pipeline infrastructure. Therefore the prevailing price in markets in which natural gas is transported can create the business case to implement technologies that can increase the amount of methane emissions that are captured. This means that natural gas prices can vary across the world, and particularly in countries where prices are controlled by the state. In these cases, offsets could play a role in incentivising deployment of methane mitigation technologies that are more expensive, and which could not recover costs due to natural gas prices that are purposefully kept low by the state.

Therefore, offsets are optimal in cases where there is little financial incentive to implement mitigation options for methane. The oil and gas industry are responsive to supply offsets when a carbon price is introduced, as can be seen in the Alberta case study in Carvalho et al. (2021). However incorporating offsets into a compliance scheme is sub-optimal in cases where there are clear commercial benefits from selling natural gas to markets, challenging the financial additionality of these projects. Overall, methane mitigation options are scored as semi-optimal to reflect a middle score between these two extremes.

3.2.5.3 Environmental and social: semi-optimal to sub-optimal

There are some potentials for co-benefits from mitigation options. Mitigation options such as flare reduction systems can improve air quality (SDG 15 on life on land), that is also related to improved health outcomes (SDG 3 on good health and well-being). Consequently, there are some co-benefits that can be realized.

However one of the key concerns is that the increased capture of methane that is sold into natural gas markets will lead to an increased consumption of natural gas that would increase emissions on the demand-side. If the natural gas displaces consumption of more carbon-intensive fuels, then this would be a positive effect on the climate. However, if such a displacement does not occur, but instead increased natural gas supply increases consumption of natural gas – particularly as it decreases market prices of natural gas – then this would be a negative effect on the climate. This outcome would suggest project leakage risk if the project boundary is not extended to the consumption of the natural gas itself, but just to the mitigation of methane emissions onsite.

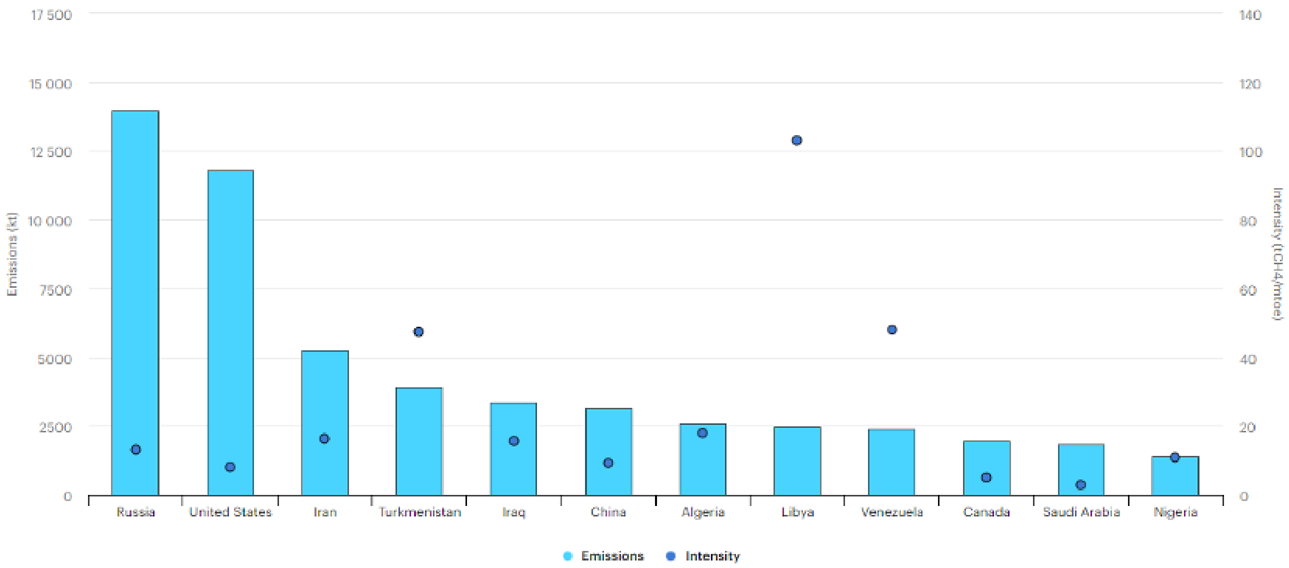
Therefore, a comprehensive assessment should be undertaken between the impact on the climate, environment, and health from mitigating methane emissions from oil and gas supply versus the combustion of natural gas from consumers. As such, this mitigation activity is rated as semi-optimal to sub-optimal.

3.2.5.4 Design considerations

Policymakers would need to carefully consider whether offsets are the most appropriate mechanism to support methane mitigation options from oil and gas production. This consideration is based on avoiding prolonged consumption of oil and gas. Oil and gas contributed to 42% of global emissions in 2015, with 33% percent from consumption of oil and gas products (McKinsey & Company, 2020a). To ensure the global economy is on track to meet the Paris climate targets, consumption of oil would drastically have to reduce. There is the case for natural gas to replace coal in power generation (IEA, 2021), particularly in countries with large coal power capacity, and particularly those that are increasing their electrification rates of transport (such as China and India). Nevertheless, it would be important for natural gas to only be an interim – rather than long-term measure – to reduce the potential impacts of climate change.

Policymakers in jurisdictions that have oil and gas production should provide incentives to oil and gas operators to reduce methane emissions. Policymakers in these jurisdictions are incentivized to continue to prolong oil and gas production due to their own economic dependence on this sector. Given these circumstances, it would be important for policymakers to consider the types of policies that would be effective in reducing methane emissions. The figure below shows the main countries who are the biggest emitters of methane from oil and gas production (IEA, 2021).

Figure 17 Top methane country emitters for oil and gas activities in 2020



Source: IEA, 2021

Policymakers in oil and gas producing countries would need to undertake assessments of where methane emissions are being released from their facilities and infrastructure. It is noted that it is difficult to measure methane emissions, though improvements in the development of infrared technologies and satellite data could support such data collection. By doing this, they could identify suitable mitigation options based on their emissions profile. Policymakers could also join international initiatives, such as the World Bank's Global Gas Flaring and Reduction Partnership, and UNEP's Oil and Gas Methane Partnership 2.0., to undertake such assessments.

Second, policymakers in oil and gas producing countries would need to consider whether they could develop the regulatory case for oil and gas operators to implement these mitigation options. The most straightforward incentive is to place a carbon price on oil and gas production. However out of the top 12 countries who produce the most methane emission from oil and gas production (as seen in Figure 18 above), only Canada has placed a carbon price on oil and gas productions, though the US state of California has also done so (World Bank, 2020). China is planning on expanding its national carbon price to emissions-intensive industries, though this does not cover emissions from oil and gas production.

The IEA is developing a regulatory toolkit that has a database of policies from countries to support methane reductions, which include technology-based standards, and performance-based incentives. Offsets could be suitable for performance-based incentive programs, as it requires the set-up of MRV systems to measure performance of methane reduction, and financially rewards the results. Offsets can thus provide payback to oil and gas operators.

If using the offset mechanism for methane reductions, policymakers would need to have rigorous crediting programs that consider the financial additionality of these projects. The offset mechanism becomes suitable in cases when the technical abatement potential exists to reduce emission exists, but the economic payback does not exist due to low natural gas prices. Offsets would thus be suitable in countries where market prices are low due to state interventions, or the market is already saturated with natural gas. Offsets could support less capital-intensive mitigation projects in these cases, such as replacement of existing devices or repairing pipeline infrastructure. It could also support flare reduction projects, though it would be important that infrastructure exists to transport increased supply of natural gas to domestic markets.

Policymakers that are not in oil and gas producing countries do not have the same political-economy constraints as policymakers in countries with oil and gas production. Policymakers that do not produce oil and gas should focus on how to support the low-carbon transition in their own country, including reducing consumption of oil and gas. It would be counterintuitive to have policies that penalize consumption of oil and gas domestically, while at the same time using the offset mechanism to support mitigation of oil and gas production internationally. Rather than use the offset mechanism, policymakers in non-oil and gas producing countries can support the efforts of international programs that help oil and gas producing countries to address their methane emissions.

3.2.6 CCUS for heavy industry

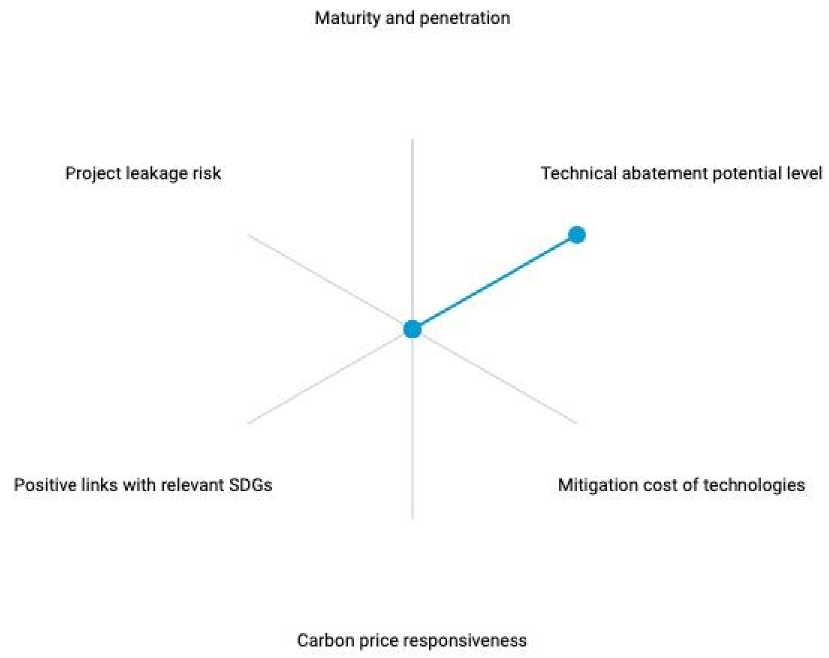
Table 18: Mitigation activity overview – Carbon capture, utilization, and storage (CCUS) for heavy industry

CCUS for heavy industry	
Mitigation activity description	Heavy industry refers to facilities that produce aluminium, cement, iron and steel, and certain petrochemicals (including plastics). The carbon captured from heavy industrial facilities can be permanently stored in materials that are used in end products or deep geological sites. If the emissions resulting from heavy industry are from fossil fuel combustion and other industrial processes, then the emissions captured and

CCUS for heavy industry	
	permanently stored by CCUS projects represent offsets that have reduced emissions that would otherwise have been released into the atmosphere from the industrial facility. CCUS for heavy industry is not a removal offset, as it does not reduce emissions that are greater than the emissions volume released from the heavy industrial facilities.
Context	It is well recognized by the IEA (2019; 2020a; 2020c) reports that CCUS for heavy industry is needed to capture and store emissions from heavy industry that are difficult to avoid due to the absence of low-carbon alternatives for fossil fuel combustion and carbon-intensive industrial processes. Though CCUS is thus needed to meet Paris targets, it is too expensive, particularly against current carbon prices. Therefore, though CCUS may be one of the key technologies to reduce significant volume of emissions in these sectors (IEA, 2019), it is not cost-effective against the carbon price. Policymakers are largely focusing on using industrial support policies to help pilot test the applications of CCUS technologies with heavy industry to improve its maturity and decrease its costs. As such, the offset mechanism is unlikely to be suitable for CCUS for heavy industry now due to high costs of CCUS projects, and low carbon price responsiveness at prevailing carbon prices.

Source: South Pole

Figure 19: Overview assessment of supply factors - CCUS for heavy industry



Source: South Pole

3.2.6.1 Technical: optimal by having the potential to reduce large amounts of emissions, but semi-optimal with regards to the maturity and penetration of technologies

The IEA (2020c) report projects that CCUS technologies will need to capture and store 430 million tonnes of CO_2 emitted from heavy industry by 2030 to meet Paris targets, as defined under their Sustainable Development Scenario. McKinsey and Company (2020a) estimates that the amount of emissions that CCUS could capture could grow from 50 million tonnes CO_2 per year in 2020 to 500 million tonnes CO_2 per year in 2030 – demonstrating a large technical abatement potential. The question however is ensuring that these captured emissions can be stored permanently, either in geological sites (such as saline aquifers or depleted oil reservoirs) or in materials (such as cement and polyurethane carbon) that are used in end products.

The Global CCS Institute (2020) reports that a Global CO2 Storage Resources catalogue is being developed to assess the geological storage potential from major storage basins, drawing on geological data developed in assessing oil and gas reservoirs. So far, it is estimated that 400 billion tonnes of storage resources have been qualified as having the potential to store CO_2 (Global CCS Institute, 2020). These assessments have so far been done for 500 sites in 80 basins across 13 countries. The Global CO2 Storage Resource catalogue will eventually assess all major storage basins in the world in the next five years, with preliminary estimates that there is a total of 12 billion tonnes of storage potential, with 98% in saline aquifers (Global CCS Institute, 2020).

Though estimates of geological storage potential appear to be sufficient for heavy industries' CCUS needs (as estimated under the IEA's Sustainable Development Scenario for 2030) (IEA, 2020c) - actual storage potential is constrained by geographical and legal factors. Heavy industry facilities may not be close to – or in the same country – as where suitable geological reservoirs exist. There is the technical potential to undertake transboundary movement of CO_2 storage between two countries through ships or land-based transport. Legally however, there are constraints under the London Protocol, an international agreement that regulates CO_2 storage in sub-seabed geological formations (Global CCS Institute, 2021). In 2019, a formal agreement was reached to allow for the 'provisional application' of a 2009 amendment to the Protocol which was previously rejected. The provisional application would thus allow for the transboundary movement of CO_2 for the purpose of geological storage if there is agreement between the countries that export and receive the CO_2 to be stored. Once both countries agree, they would need to do further notification procedures set by the International Maritime Organization. In this way, transboundary movement of CO_2 will be limited to countries that meet these legal requirements.

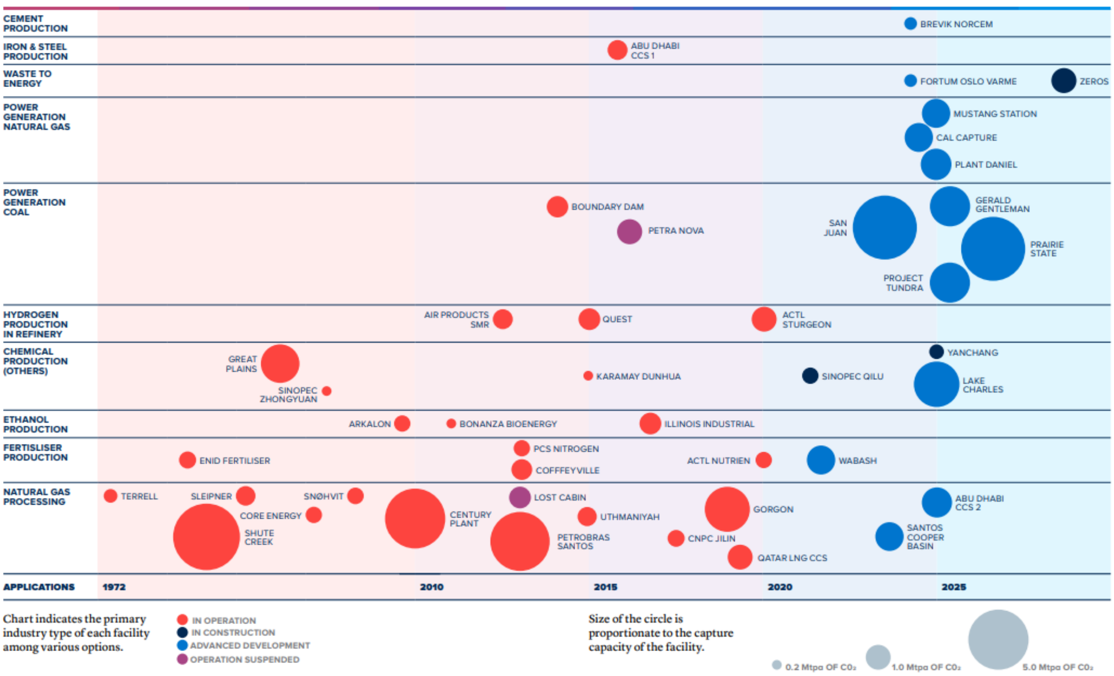
CCUS is more geographically and legally viable for heavy industrial facilities that are in the same country as geological sites. Furthermore, it is more viable to countries that already have infrastructure that can transport the captured CO_2 – such as pipelines – to the geological sites. The oil and gas sector is more amenable to have access to pipeline infrastructure and depleted oil reservoirs to use CCUS to abate their residual emissions.

Storing captured emissions in materials would be more amenable to the cement, petrochemical sectors, and iron and steel. These materials could then be used in buildings, and consumer products such as mattresses or yoga mats (Carbon XPrize, n.d.; Global CCS Institute, 2020; McKinsey and Company, 2020a). McKinsey and Company (2020a) estimates that 150 million tonnes CO_2 per year could be stored in materials such as cement, and 10 million tonnes CO_2 per year in polyurethane carbon (produced by the petrochemical industry) by 2030. There could be an increase in the types of materials (e.g. carbon fiber) using captured emissions, which could increase future storage potential. However, industrial facilities that use the captured emissions for applications that would not permanently store these emissions – such as carbon dioxide emissions used for enhanced oil recovery – should not be considered for offsets.

Despite the technical abatement potential of CCUS, the maturity and penetration of technologies at different stages of the process are mostly in the prototype and early adoption stages (IEA, 2020a). CCUS is 'catch all' term for a series of technologies: the technologies used to capture emissions from industrial facilities (with different industrial sectors requiring its own type of capture technology), modes of transport, and then technologies that permanently store emissions. A review of IEA's Clean Energy Technology Guide reveals that most technologies that capture CO_2 from industrial facilities, and technologies used to store CO_2 in materials are just at the concept validation, prototype or early demonstration stage (with TRL scores ranging from 4 to 8) (IEA, 2020a). Pipeline and geological storage are more mature by being at the early adoption stage (with TRL scores of 9 to 10). CCUS is thus scored as having semi-optimal maturity due to this range.

As shown in Figure 20, the penetration of CCUS technologies is low as most operating projects are still at the early demonstration stage (Global CCS Institute, 2020). According to the Global CCS Institute 2020 status report for CCS, there are currently 65 CCS plants globally,[4] with only 26 in operation, three under construction and the others at various stages of innovation and development (Global CCS Institute, 2020). Two facilities are suspended, with one due to the economic downturn and the other due to fire. Those in operation and construction have the capacity to capture and permanently store around 40 million tonnes of CO_2 every year. In addition, there are 34 pilot and demonstration-scale CCS facilities (operating or about to be commissioned) and eight CCS technology test centers. Therefore, while there are projects in operation, there still needs to be greater maturity – particularly for CCUS applied to different heavy industry sectors – for them to become an attractive option for offsets. Thus they are scored as being

Figure 20: Status of CCS facilities in power and industrial applications



Source: Global CCS Institute Report, 2020

[4]38 of these facilities are in the Americas, thirteen in Europe and ten in Asia Pacific.

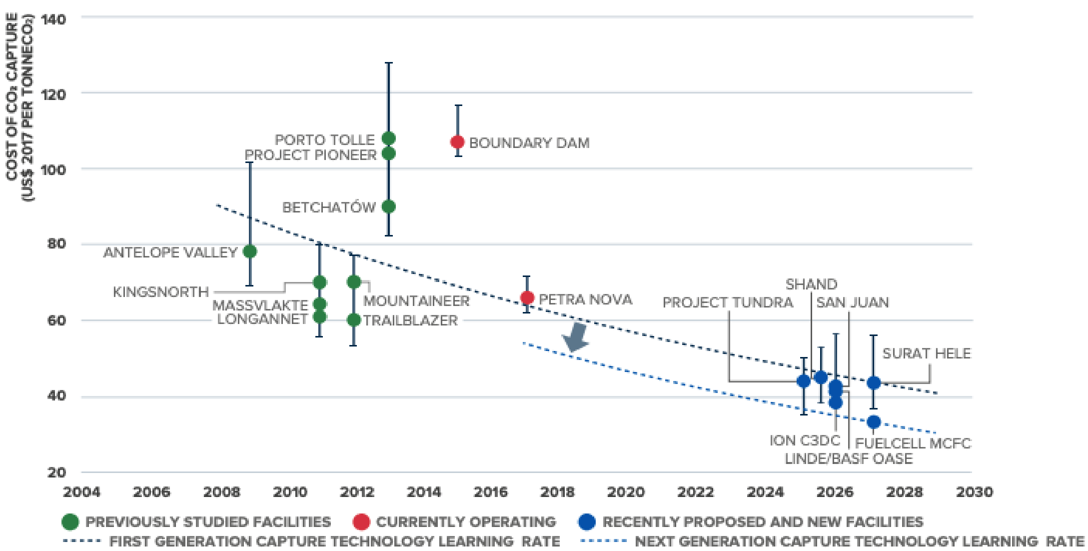
3.2.6.2 Economic: sub-optimal as costs of mitigation are much higher than compliance price signals

In theory, offsets could play a role in overcoming the economic barrier of CCUS technologies if buyers are willing to pay a high offset price. Cost of CCUS is a major impediment to its deployment (McKinsey & Company, 2020b). The technologies used to capture emissions from industrial facilities of CO_2 is particularly expensive – costing USD 50 to 100 per tCO_2e (McKinsey & Company, 2020b). The costs of these capture technologies will differ depending on the industrial facilities and geography, as can be seen in Figure 21 below. Transport and storage costs are highly variable as well, as it depends on type (and length) of transport to storage sites, and storage sites themselves.

It should be noted though that these reports do not include the costs of implementing MRV systems through the entire project lifetime. MRV system costs would need to be included as part of CCUS projects' costs as there would need to be accurate measurements on the volume of emissions that are permanently stored to be certified as offsets. The costs of implementing MRV systems are dependent on the size of the project boundary (from capture, transfer and storage) and project lifetime to demonstrate permanence. The International Panel on Climate Change (2006) defines permanence of emission reductions as being more than 100 years. Therefore, CCUS projects would need to include costs of operating MRV systems for 100 years.

Currently, the cost of CCUS deployment is still far higher than the average carbon price employed by most carbon pricing schemes around the world. The figure below shows the suggested cost abatement from existing and future facilities from CCUS projects, with costs that are much higher than the current global average carbon price of USD 3 to 5 per tCO2e calculated by Trove Research and UCL (2021). Currently, at least half of global emissions under a carbon price face costs that are less than USD 10 per tCO2e, and less than 5% of global emissions are priced at a level between USD 40 to 100 per tCO2e (World Bank, 2020). The costs of CCUS technologies would have to reduce to be cost-effective against forecasted carbon credit prices, estimated at USD 20 - 50 per tCO2e by 2030, and greater than USD 50 per tCO2e by 2050 (Trove Research and UCL, 2021). This comparison indicates that until CO2 can be captured and stored more cheaply – or carbon prices rise substantially – there is no business case to sell offsets in compliance schemes. Therefore, the carbon price responsiveness is low.

Figure 21: Cost abatement from CCUS projects in existing and future facilities



Source: Global CCS Institute Report 2019

3.2.6.3 Environmental and social: sub-optimal

CCUS technologies applied to the heavy industry sector would not provide strong co-benefits. Compared to the other supply-side mitigation activities and sectors examined, CCUS and heavy industry impact relatively few SDGs positively, except for SDG 7 (affordable and clean energy) and 9 (industry, innovation and infrastructure). As a result, in this category, the sector is classified as 'low'.

Furthermore, this type of mitigation activities could be in danger of creating environmental and social harm. Captured GHG emissions need to be transported through pipelines, or captured in storage units and transported by vehicles to the end destination. In the case of pipelines, strong environmental impact assessments would be needed to address potential environmental impacts from developing large-scale infrastructure. Furthermore the accidental release of large volume of emissions transported through pipelines or stored in a deep geological site could pose serious risks for the climate, the environment and human health. It would be important to have robust MRV systems that have strong leakage detection technologies to be implemented along pipelines and storage facilities to monitor and minimize any release of emissions. These MRV systems would also need to have long operating lifetimes as they are important for addressing non-permanence issues.

CCUS could also have project leakage risk from emissions stored in materials, depending on how the project boundary is drawn. Conceptually, the project boundary should encompass capture, transfer and permanent storage of emissions. The project boundary is easier to define when the final storage is geological sites, so that the release of emissions from geological sites could be considered within the project boundary. However, drawing the project boundary is more complicated for carbon dioxide stored in materials, such as cement and plastics that are then used in end-products. Optimally, the project boundary should extend to how it is stored in end products – in which case, any release of emissions caused by product deterioration are considered within the project boundary and cannot be counted as project leakage if emissions are released. However it is likely that it would be difficult for MRV systems to monitor emissions that could be released due to product deterioration, particularly for consumer products. For practical purposes, MRV systems could create project boundaries to the material in which CO_2 is stored rather than extending the boundary to the end-product. The problem drawing the boundaries of MRV systems in this way is that it would be difficult to detect non-permanence issues due to product deterioration. Furthermore, it would be classified as project leakage as it would result in emissions released outside the MRV system's project boundary. Therefore, this report scores CCUS technologies as having semi-optimal risk of project leakage *if* project boundaries are only drawn to materials, and not end products. For this reason, this report rates the risk of project leakage to be semi-optimal to highlight the complexity of drawing project boundaries for CO_2 stored in end products.

3.2.6.4 Design considerations

There is a question of whether CCUS technologies would lock-in economic dependence on the outputs from heavy industry in the long-run, rather than support the development of alternatives that have a much smaller (or negligible) carbon footprint. Policymakers should also prioritize fundamental transformation of the inputs and processes of heavy industry to support its decarbonization, which would thus reduce the reliance on CCUS to capture and store residual emissions. It would be important for policymakers to take these considerations into account when determining whether to allow CCUS technologies to supply offsets from existing industrial facilities. Offsets from CCUS projects should only be used as an interim instrument to capture emissions from heavy industry that are difficult to avoid. Over time, these unavoidable emissions should reduce as heavy industry decarbonizes.

Policymakers would also need to ensure that offsets from CCUS projects involved with heavy industry have viable storage potential to ensure permanence of stored emissions. Given the geographical and legal constraints of transporting CO_2 across borders, policymakers would need to assess whether their jurisdiction has geological reservoirs that can permanently store CO_2, along with transport infrastructure that can bring the captured CO_2 from the industrial facilities to geological sites.

To ensure the environmental integrity of the compliance scheme, policymakers should exclude CCUS projects that are difficult to track and monitor permanence of stored emissions. Therefore the project boundaries of MRV systems should be clearly defined to track stored emissions to its end-use. Policymakers could exclude carbon stored in materials that go into products that are prone to deterioration before the time period set for permanence. It is recommended that policymakers use the IPCC definition of permanence that indicates a minimum period of 100 years. Consequently, products that deteriorate or are thrown into landfills within 100 years of production should be excluded. Policymakers could invest in more sophisticated monitoring and detection systems to ensure permanence of emissions in CCUS projects that do qualify for supplying offsets from heavy industry. These systems would also be important to minimize any adverse environmental and social consequences from emissions leakage.

To further uphold the environmental integrity of the compliance scheme, the crediting mechanism would need to have buffer mechanisms in place, like a reserve pool of carbon credits, that would be cancelled upon the notification of any leakage. If a project's crediting period has ended, the owner can cancel all remaining credits that are held in the buffer reserve for the project to account for any accidental future release of emissions (a risk mechanism that is done by the Verified Carbon Standard).

The expansion of novel CCUS technologies is limited however by the high costs associated with it. The introduction of offsets can help alleviate CCUS high prices – assuming that policymakers are willing to implement explicit or implicit compliance prices that would create a business case to sell offsets from these projects. However, to date, it does not seem that current compliance prices, nor the market prices for offsets, would be high enough to provide sufficient financial support for CCUS technologies to escalate. Policymakers should be aware that CCUS technologies may first need to benefit from industrial support policies to improve their economic and technological viability before it can be financed through offsets revenues.

3.2.7 Bio-energy CCUS

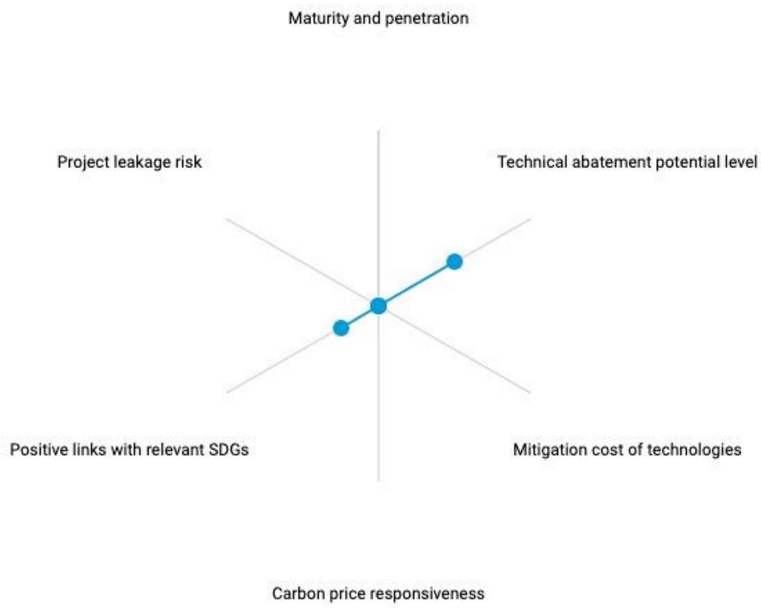
Table 19: Mitigation activity overview - bio-energy CCUS

Bio-energy CCUS	
Mitigation activity description	Bio-energy CCUS can be used to provide power for electricity generation and industrial facilities, or be incorporated into the production of biofuels (Consoli, 2019). Bio-energy is considered to be a removal technology as the biomass would have captured and stored carbon from the atmosphere. Their combustion in bio-energy facilities would be captured and permanently stored in geological storage sites or in materials that are used for end products. Therefore, in terms of carbon accounting, bio-energy CCUS has an overall negative emissions effect due to the carbon that was removed from the atmosphere, and then permanently stored.

Bio-energy CCUS	
Context	Bio-energy CCUS has the potential to reduce emissions from existing coal and thermal power plants by substituting the original input source with biomass, which has a lower carbon intensity than fossil fuels at the point of combustion. Therefore, the combustion of the biomass would reduce emissions from the plant by being a low-carbon substitute to the original thermal fuel source. Nonetheless, bio-energy CCUS is controversial due to the reliance of biomass that could lead to project leakage by potentially incentivising increased deforestation and degradation to provide biomass inputs. To avoid this, it would be important to ensure that the sourced biomass comes from residues of existing agricultural, forestry or waste streams. As such, this technology is a more interesting option for industrial facilities that have direct access to such residues, such as pulp and paper, ethanol production or waste plants. This technology also requires access to deep geological formations that can permanently store the carbon (referred to as carbon capture and storage). Alternatively, there needs to be supply chains that can safely deliver the captured emissions to industrial facilities that can then embody the carbon into products that permanently 'store' the emissions. Robust MRV systems and safeguards needed to ensure emissions are permanently stored as in every CCUS deployment.

Source: South Pole

Figure 22: Overview assessment of supply factors - bio-energy CCUS



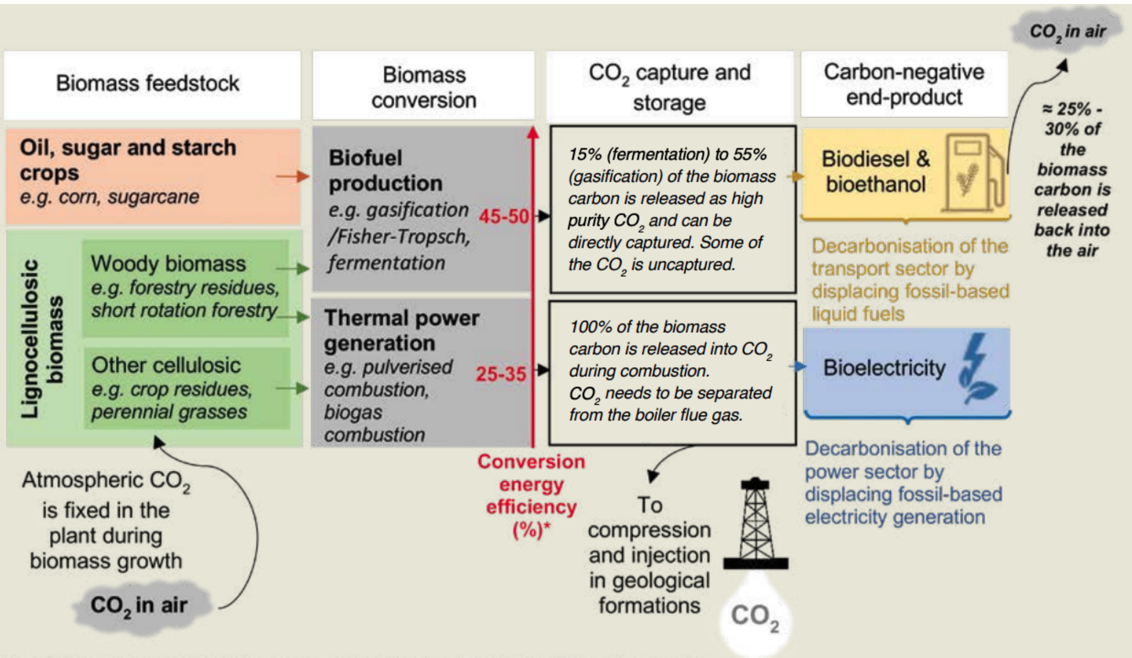
Source: South Pole

3.2.7.1 Technical: sub-optimal or semi-optimal for specific technologies

Bio-energy CCUS are novel technologies with low maturity and penetration in the market. Most climate change integrated assessment models (IAMs) feature the deployment of bio-energy CCUS technologies (Fajardy et al., 2019). Currently, the penetration of bio-energy CCUS is limited to five facilities in the world. Four of these facilities are involved with ethanol production in the US, while the Drax plant in the UK is the only operating bio-energy CCUS plant that has converted from a coal plant to biomass plant, and then successfully operated a pilot CCS technology (Fajardy et al., 2019). While most bio-energy technologies are mature, the technologies based on carbon capture are less mature. The other limitation is having access to geological storage facilities that can provide ‘permanent’ seals of 100 years or more, or storing the carbon in end products that will no deteriorate in a 100 year time period.

Therefore, this technology is considered to be sub-optimal from a technical assessment given the immaturity of capture technology, the low penetration of these technologies, the need to monitor the carbon footprint of biomass sources, and ensuring permanence of stored emissions. This technology could be considered semi-optimal for certain industries where access to biomass residues is readily available, such as pulp and paper, agriculture or forestry. It would also be semi-optimal for industrial applications for bio-ethanol production. Figure 23 below provides different routes of bio-energy CCUS.

Figure 23: Biomass conversion routes for bio-energy CCUS



Source: Fajardy et al., 2019

3.2.7.2 Economic: semi-optimal to sub-optimal

The elevated costs associated to mitigation activities applying CCUS technologies result in a low carbon price responsiveness. The economic cost of different bio-energy CCUS technologies varies across applications, as shown in Table 20 below. While the lower range of ethanol, pulp and paper, and biomass gasification technologies suggest abatement costs that are within the range of current carbon price, the middle and upper ranges suggest costs that are outside of current carbon prices or carbon prices that are aligned with science-based targets. The High-Level Commission on Carbon Prices suggest that carbon prices would need to be at least USD 40-80 per tCO2e in 2020, and increase to USD 50-100 per tCO2e in 2030 to be in line with Paris targets (Stiglitz & Stern, 2017).

Furthermore, the high upfront costs of installing the capture technology, along with the costs of building out transport and storage infrastructure, demonstrate that the mitigation costs are high. The capital-intensiveness of this technology does not provide a carbon price responsive option for power or industrial facilities.

Table 20: Cost of CCS applied to different sectors

Sector	CO_2 avoided cost (USD/tCO_2)*
Combustion	88 - 288
Ethanol	70 - 175
Pulp and paper mills	20 - 70
Biomass gasification	30 - 76

Source: Consoli, 2019 *Note: It is unclear whether these costs include the MRV systems needed to be put in place for at least 100 years to ensure permanence.

3.2.7.3 Environmental and social: semi-optimal to sub-optimal

The potential for co-benefits is limited and the risk of negative environmental and social impact is high. While bio-energy CCUS is clearly featured in IAM models of the IPCC as a way to meet Paris targets, if the upper bounds of the bio-energy CCUS targets were reached, it would require an amount of biomass that is three times the world's productions of cereal, twice the annual use of water for agriculture and twenty times the annual use of nutrients (Fajardy et al., 2019). The unintended social consequence is that it could drive up the price of essential resources such as agriculture and water.

If biomass was grown to meet the demands for bio-energy CCUS, it could thus have negative environmental consequences in increased deforestation, putting greater stress on ecological systems and displacement of forestry communities. Consequently, the project leakage risk is sub-optimal as emissions are released outside the project boundary of bio-energy CCUS due to increased deforestation and degradation. There should be careful use of this technology, restricted potentially only to those facilities that have easy access to biomass waste residues that would otherwise decompose if they were not used.

As mentioned in CCUS for heavy industry, there is an environmental risk involved with the build out of the infrastructure needed to move the captured carbon from the generation site to the final storage. Furthermore, the final storage needs to ensure that it can safely seal and monitor any emissions released into the atmosphere for at least 100 years to ensure permanence. A large amount of emissions released into the atmosphere not only has climate change consequences, but also environmental, social and health consequences from the sudden release of emissions.

3.2.7.4 Design considerations

Given the immaturity of the capture technology, policymakers can consider instituting industrial policies to provide funding to deploy bio-energy CCUS to existing industrial facilities that have access to biomass residues and can ensure emissions are permanently stored. The industrial facility can use the electricity for its own purposes or the power grid, potentially lowering the emission factor of the power grid if it mostly relies on fossil fuel consumption. Once the costs of bio-energy CCUS reduce to being close to commercial viability, policymakers can consider allowing more industrial facilities with access to biomass residues and ways to permanently store emission (either in geological storage sites or final products) to be financed through the offset mechanism.

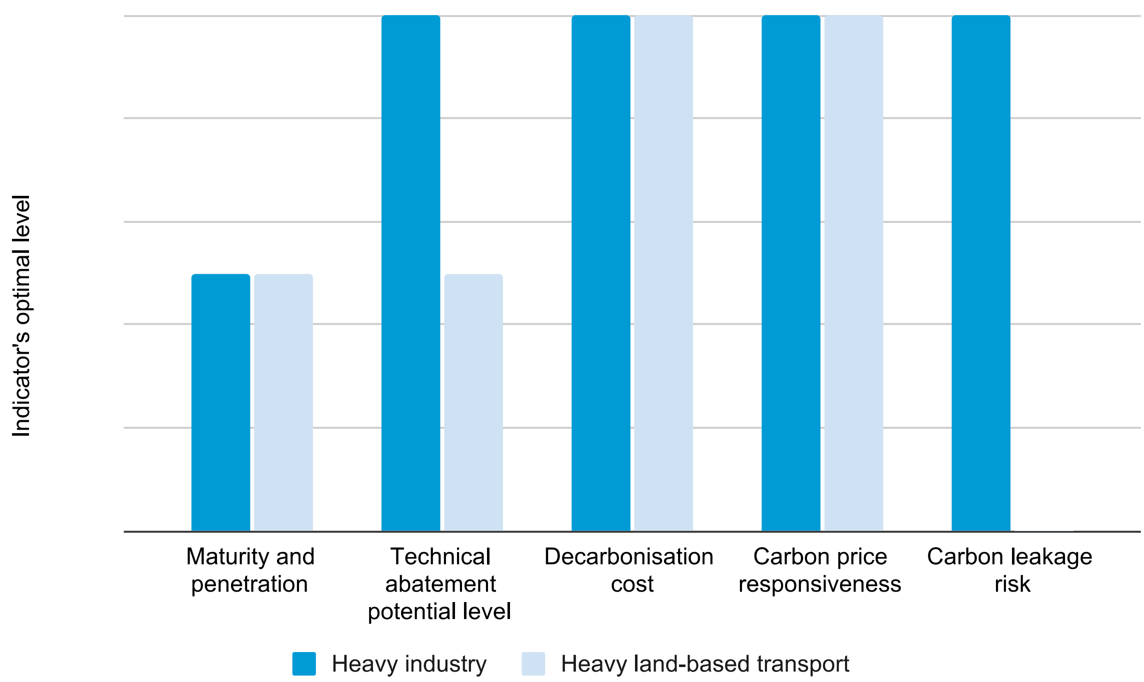
Like heavy industry CCUS, policymakers need to undertake very careful accounting of the emissions that are captured from the facility and then transferred to industrial applications for non-permanent storage, versus those that are transferred into industrial applications that store carbon in products or in geological sites. This carbon accounting would also need to monitor the risk of carbon being emitted back into the atmosphere if the end product or storage site is compromised.

While the carbon footprint of supplying the biomass inputs would most likely be less than mining for coal and or extracting natural gas, it would still be important for policymakers to ensure that biomass sources do not lead to increased deforestation and land degradation because of sourcing biomass to meet the needs of the bio-energy plant. Policymakers who are thinking of converting existing thermal plants, such as coal and natural gas plants, to biomass generation would need to ensure that the source of biomass inputs would be derived as by-products of existing agriculture or pulp and paper mills. It could be environmentally prudent to only allow CCUS for facilities that have biomass as a by-product of their operations, once the capture technology becomes more mature and the costs of mitigation decrease.

3.3 Sectors/mitigation activities comparison

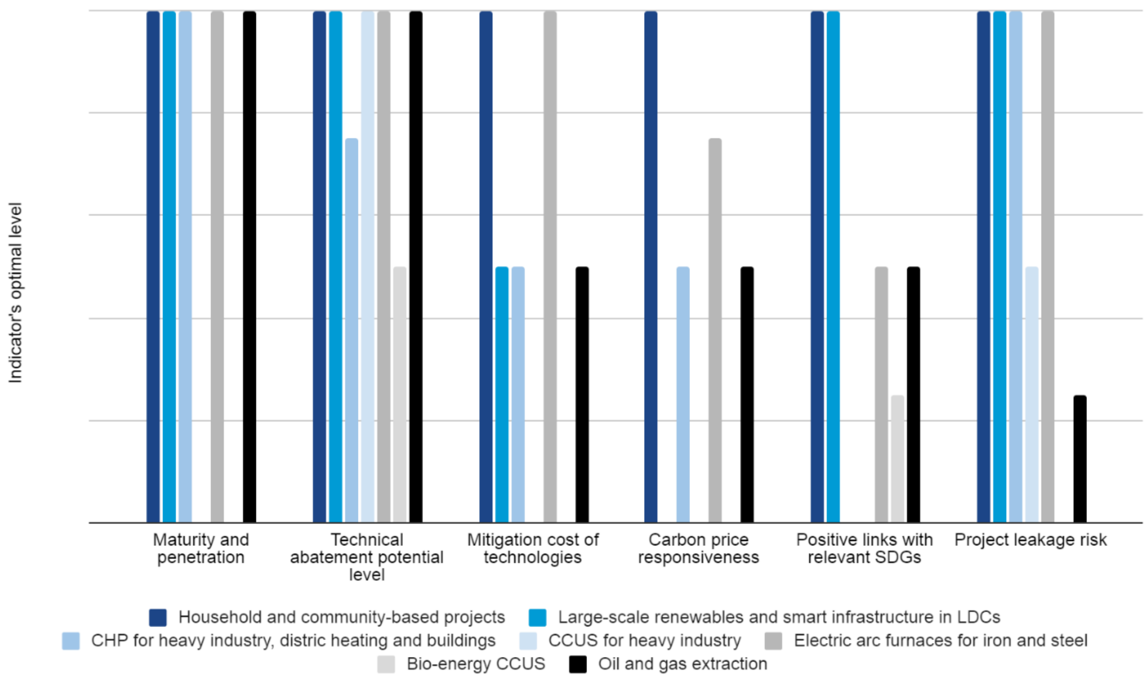
The uneven and different shapes of the radar charts in section 1.1 and 3.2 exhibit the differences among sectors/specific mitigation activities regarding the factors that determine suitability related to demand and supply offsets. Figure 24 and Figure 25 show those differences within the sectors and mitigation activities analysed on the demand and supply side respectively.

Figure 24: Demand-side success factors assessment across selected sectors



Source: South Pole

Figure 25: Supply-side success factors assessment across selected mitigation activities



Source: South Pole

Since in some cases factors will be present at a sub-optimal level, careful adaptation of the design of the mechanism to these conditions would be crucial. Failing to analyse and address these sub-optimal factors can result in a carbon scheme that does not uphold environmental integrity, raise ambition of the compliance scheme or promote sustainable development. Success factors have different weights depending on the sector/specific mitigation activity and the context.

Policymakers must examine the interaction among success factors and the substantial effect the context can have on the results of this study. Design considerations will be key for a government to:

- successfully select the sectors/specific mitigation activity that will be allowed to demand or supply carbon offsets under a compliance scheme; and
- tackle the sub-optimal factors that a sector/specific mitigation activity might have in regard to its qualification to demand/supply offsets and, as a result, in regard to its capacity to uphold environmental integrity and raise ambition of the compliance scheme while promoting sustainable development.

4 Consolidated results and recommendations

As the earth's average temperature continues to rise, the need to implement stringent climate policy regimes grows by the day. In light of the significant decarbonization challenges facing numerous sectors, carbon offsets can serve as a cost-containment measure for stringent compliance schemes in the short- and medium-term. On the supply side, the revenues from the sale of these offsets could further provide much of the funding needed to accelerate the deployment of low- and zero- carbon technologies and solutions that would otherwise be inaccessible, along with achieving SDG co-benefits. It is important to emphasize that offsets – whether in terms of demand or supply - should only be incorporated into a compliance scheme when they are able to uphold the environmental integrity of compliance schemes, raise the scheme's climate ambition and promote sustainable development. To be considered successful, an offset mechanism must satisfy all three of these requirements.

Building on Carvalho et al. (2021) and Kreibich et al. (2021), this report seeks to support policymakers in the identification of sectors that could qualify to surrender offsets for compliance purposes, and mitigation activities that could qualify for generating offsets to be used by compliance actors. It is important to note that the presented approach to determining which sectors should be eligible to either demand or supply offsets is a **general** one, and policymakers should consider jurisdictional context to determine whether and how offsets can be incorporated into the sectoral crediting mechanism. In addition, policymakers should keep in mind the **temporal aspect** when utilizing this methodology. Carbon offsets should be seen as an interim measure, and the decision of which sectors/mitigation activities should be included in the demand and supply sides must be revised regularly as mitigation options become more easily deployed. As technologies improve and increase their market penetration and the costs of decarbonization fall, the need for offsets as a cost-containment measure will be diminished for demand sectors. This temporal aspect also applies when mitigation activities go from being inaccessible to more accessible, and therefore no longer qualify for supplying offsets.

To assess how offsets can be incorporated into compliance schemes, it is extremely important for policymakers to first conduct technological assessments and develop roadmaps to identify hard-to-abate sectors and currently inaccessible mitigation options. Not undertaking this kind of assessment can lead to a violation of the principles of success, particularly with regard to offsets not raising ambition of the compliance scheme or creating perverse incentives that undermine environmental integrity. Alternatively, policymakers may also miss the opportunity by not by not developing an appropriate sectoral baseline. This baseline is important in identifying hard-to-abate sectors that could use offsets as a cost-containment measure. Policymakers could also use the sectoral baseline to drive emission reductions for options that are identified as being inaccessible. The suggested steps to develop a sectoral baseline and technological roadmap include:

- Step 1: Undertake an on-the-ground survey to understand the emissions-intensity of technologies currently implemented in each jurisdiction's sector.
- Step 2: Identify which types of mitigation options are available to the sector. While there are several resources that can facilitate an understanding of the sectoral mitigation options at the global level, it would be important to see which of these options are appropriate to the sectoral context of the country. From identifying these mitigation options, policymakers should consider whether these mitigation options could be realized within the scope of the compliance scheme (based on the costs and commercial availability of the mitigation options, or whether policies could create the incentives to drive mitigation). Policymakers

can then measure the potential emission reductions that could be achieved by these mitigation options (including with support policies) to develop a sectoral baseline. Policymakers could also develop technological roadmaps to provide time periods in which they expect mitigation options that are not counted towards the current baseline to be incorporated into the future sectoral baseline, based on an assessment of how policies and technologies could evolve to enable these mitigation options to be implemented in the future.

- Step 3: Identify mitigation options that go beyond sectoral baselines could be considered for offset use. Policymakers should first consider whether other types of policies would be more appropriate to address hard-to-abate emissions or support deployment of mitigation options, rather than the use of offsets. The following recaps whether sectors can demand offsets, or mitigation options can supply offsets.

To determine which domestic sectors could qualify to **demand offsets**, the proposed methodology assesses whether and how a sector is considered 'hard-to-abate'. This is based on the interplay of the stringency of climate policies imposed upon sectors, the technical mitigation potential and economic costs associated with decarbonisation. If this interplay suggests that the compliance scheme would cover emissions that are technically unavoidable, costly to reduce and could trigger carbon leakage, then it would qualify for the need for cost-containment measures. For example, sectors that have limited potential to abate would, all else equal, be more likely to be deemed eligible to surrender offsets for compliance than other sectors that can abate relatively easily. This demand-side methodology was applied to the heavy industry and heavy land-based transport, demonstrating that heavy industry may have more optimal conditions than the latter towards using offsets as cost-containment measures.

Policymakers could be interested in using the offset mechanism to realize inaccessible emission reductions domestically or in external jurisdictions through allowing these projects to **supply offsets.** In the latter case, policymakers would need to work with host country governments to develop the sectoral baselines and technological roadmaps. As explained in section 2, the methodology considers the different factors that policymakers need to consider in developing a sectoral baseline to determine which mitigation options are qualified as being inaccessible. To determine which mitigation options could be eligible to supply offsets at the global level, it also assesses technical mitigation potential, the cost of abatement and contribution to the SDGs. The assessment of SDGs also requires ensuring any risks of negative social and environmental impacts are minimized and managed appropriately in order to do 'no net harm'.

The following mitigation activities were selected to apply the supply-side methodology: household and community-based projects in LDCs; large-scale renewable energy generation and smart systems in LDCs; combined heat, power and cooling for heavy industry and buildings; electric arc furnaces for iron and steel; methane mitigation options for oil and gas production and distribution; CCUS for heavy industry; and bio-energy with CCUS. The main conclusion is that the mitigation activities located in LDCs were more likely to have the optimal conditions to realize the value from supplying offsets (assuming robust governance and accounting systems), while the other mitigation activities would need further contextual consideration to determine whether offsets would drive emission reductions beyond sectoral baseline. CCUS (with or without bio-energy) projects were considered to be the least optimal across different success factors, requiring stringent MRV systems to ensure the environmental integrity of emission reductions. If such issues are credibly addressed, CCUS for heavy industry will be an important option for addressing residual emissions of heavy industry, while bio-energy with CCUS is appropriate specifically for powering those industries that already have access to biomass residues.

As demonstrated, applying the methodology to different sectors/mitigation options shows that each has a unique profile regarding whether it has optimal or sub-optimal factors to be eligible to demand or supply offsets. Policymakers are likely to find **sub-optimal factors** that need to be considered when designing the compliance scheme. Failing to address these **sub-optimal factors on the demand side** can result in perverse incentives of compliance actors not reducing their own emissions, and an overall increase in emissions if the compliance mechanism is not properly designed to adjust for the import of offset supply. **Sub-optimal factors on the supply side** can affect the quality of an offset. Consequently, the design is important in ensuring that offsets can support transformative change for the sector by making inaccessible mitigation options more accessible.

For both the demand and supply of offsets, policymakers need to track how costs of mitigation options are changing over time for the associated sector, so that emissions that were previously unavoidable can be realized within the sector. In this case, the sectoral baseline would need to be lowered to reflect steeper reductions based on decarbonisation costs becoming less prohibitive and within a range that would not lead to carbon leakage. The implication is that the number of offsets that demand sectors could use reduces over time. The changing of the sectoral baseline to include specific mitigation options means that they no longer can supply offsets. Policymakers can include new mitigation options that could realize inaccessible emissions through the offset mechanism – thereby driving further emission reductions in offset sectors. Therefore, it is important for policymakers to keep abreast of technological developments of sectors so they can update their own sectoral baselines on a regular and periodic basis to continuously drive sectoral decarbonisation through the offset mechanism. Such an assessment would also strengthen the credibility of NDC targets as they are updated every five years.

Another key design consideration that policymakers need to be aware of is setting up robust registries and infrastructure to track emission reductions achieved through market and non-market activities. Emission reductions achieved by the market are certified as offsets and can be sold to others, while emission reductions that are achieved within the sector are just reflected in the sectoral inventory, and cannot be sold to others. REDD+ registries, or Colombia's RENARE (as described in Carvalho et al., 2021) are examples of how such registries can be developed and are important in terms of enabling corresponding adjustments between sectors where offsets originated, to those in which offsets are surrendered. This tracking ensures that both national and international GHG inventories do not double count mitigation outcomes. Furthermore, policymakers need to ensure that sectoral crediting mechanisms incorporate strong MRV detection systems and governance processes to avoid adverse environmental and social consequences from mitigation activities and address any risks of non-permanent emission reductions.

Last, this report argues that policymakers should align the design of the offset approach with the principles of success. This alignment would ensure the incorporation of offsets would add value while upholding environmental integrity of the compliance scheme. This alignment would also include the adaptation to the requirements of **Article 6 and the Paris Agreement** to ensure future-proofing. Factors' optimal levels would differ for demand and supply sectors, and so would the related design options. Specific design features, such as dynamic baselines, limited crediting periods and sunset clauses can be addressed while allowing for the offset approach to be integrated into a sound policy mix to fight climate change.

5 List of references

Acworth, W., Kardish, C., & Kellner, K. (2020): Carbon leakage and deep decarbonization: Future-proofing carbon leakage protection. ICAP. https://icapcarbonaction.com/en/?option=com_attach&task=download&id=694.

Adenbaum, J., Copeland, A., & Stevens, J. (2019): Do long-haul truckers undervalue future fuel savings? Energy Economics, (81), 1148-1166. https://www.sciencedirect.com/science/article/pii/S0140988319301719

Åhman, M. (n.d.): Perspective: Unlocking the "hard-to-abate" sectors. WRI. https://files.wri.org/expert-perspective-ahman.pdf

BNEF (2017): 4Q 2017 Frontier Power Market outlook. BNEF. https://data.bloomberglp.com/bnef/sites/14/2017/11/Master-_-Frontier-Power-MO_EL_IO_EL_IO.pdf

Carbon XPrize (n.d): Products: Carbon XPrize. https://carbon.xprize.org/prizes/carbon/products

Carvalho, M., Meneses, M., Amellina, A., Alvarez Campo, C. & Kreibich, N. (2021): Offset approaches in existing compliance mechanisms - Adding value and upholding environmental integrity? (Climate Change: 58/2021), German Environmental Agency.

Carvalho, M., Sherman, L., Álvarez Campo, C. & Kreibich, N. (2021): Potentials for Offset Approaches in Selected Sectors after 2020. (Climate Change: 60/2021), German Environmental Agency.

Columbia University Center on Global Energy Policy (2019): Low-carbon heat solutions for heavy industry: Sources, options, and costs today. Colombia University Centre. https://energypolicy.columbia.edu/sites/default/files/file-uploads/LowCarbonHeat-CGEP_Report_100219-2_0.pdf

Consoli, C. (2019): Bioenergy and carbon capture and storage. Global CCS Institute. https://www.globalccsinstitute.com/wp-content/uploads/2019/03/BECCS-Perspective_FINAL_18-March.pdf

Cundale, K., Thomas, R., Malava, J. K., Havens, D., Mortimer, K., & Conteh, L. (2017): A health intervention or a kitchen appliance? Household costs and benefits of a cleaner burning biomass-fuelled cookstove in Malawi. Social Science and Medicine (183), 1-10. https://core.ac.uk/download/pdf/224770604.pdf

Day, T., Schiefer, T., Tewari, R., Kachi, A., Warnecke, C., Mooldijk, S., Dransfeld, B., Wehner, S., & Brauhardt, L. (2020): Indicators for the promotion of sustainable development in carbon market mechanisms. (Climate Change: 46/20). Germany Environment Agency. https://www.umweltbundesamt.de/publikationen/indicators-for-the-promotion-of-sustainable

DC REEI (n.d): The Lead Developed Countries Renewable Energy and Energy Efficiency Initiative for Sustainable Development. UN.

Dechezlepretre, A. & Sato, M. (2017): The impacts of Environmental Regulations on Competitiveness. Review of Environmental Economics and Policy (11), 183-206. https://academic.oup.com/reep/article/11/2/183/4049468

Energy and Climate Intelligence Unit (n.d): Net Zero Tracker. Energy and Climate Intelligence Unit. https://eciu.net/netzerotracker

Energy Data (n.d.): Global Solar and Wind Atlas. World Bank.

European Commission (n.d.): Climate action. European Commission. https://ec.europa.eu/clima/policies/ets/allowances/leakage_en#:~:text=Carbon%20leakage%20refers%20to%20the,increase%20in%20their%20total%20emissions.

Energy Transitions Commission (2018): Mission possible: Reaching net-zero carbon emissions from harder-to-abate sectors by mid-century. Energy Transitions Commission. https://www.energy-transitions.org/wp-content/uploads/2020/08/ETC_MissionPossible_FullReport.pdf

Fajardy, M., Koberle, A., MacDowell, N., & Fantuzzi, A. (2019): BECCS deployment: a reality check. Grantham Institute, Imperial College. https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/BECCS-deployment---a-reality-check.pdf

Grantham Research Institute on Climate Change and the Environment (2018): What is carbon capture and storage and what role can it play in tackling climate change? Grantham Research Institute on Climate Change and the Environment. https://www.lse.ac.uk/granthaminstitute/explainers/what-is-carbon-capture-and-storage-and-what-role-can-it-play-in-tackling-climate-change/

Global CCS Institute (2019): Global Status Report. Global CCS Institute. https://www.globalccsinstitute.com/resources/global-status-report/

Global CCS Institute (2020): Global Status Report. Global CCS Institute. https://www.globalccsinstitute.com/wp-content/uploads/2021/03/Global-Status-of-CCS-Report-English.pdf

Global Commission on Business and Sustainable Development (2016): SDGs & Sectors: A review of the business opportunities. Global Commission on Business and Sustainable Development. http://s3.amazonaws.com/aws-bsdc/SDG-Sectors.pdf

Grasso, M. (2019): Oily politics: A critical assessment of the oil and gas industry’s contribution to climate change. Energy Research & Social Science (50), 106-115.

Hammond, W., Axsen, J., & Kjeang, E. (2020): How to slash greenhouse gas emissions in the freight sector: Policy insights from a technology-adoption model of Canada. Energy Policy (137). https://www.sciencedirect.com/science/article/abs/pii/S2214629618306376

Hiterski (2020): The beginning of the end: RE-VER projects. Redshaw Advisors. https://redshawadvisors.com/the-beginning-of-the-end-re-ver-projects/

ICAP (2020): Emissions trading worldwide – Status report 2020. ICAP. https://icapcarbonaction.com/en/icap-status-report-2020

IEA (2010): Energy Technology Perspectives: Scenarios & Strategies To 2050. IEA. http://www.oecd-ilibrary.org.ezproxy.library.uq.edu.au/energy/energy-technology-perspectives-2010_energy_tech-2010-en

IEA (2017): Energy Technology Perspectives 2017. IEA. https://www.iea.org/reports/energy-technology-perspectives-2017

IEA (2019): World Energy Outlook 2019. IEA. https://www.iea.org/reports/world-energy-outlook-2019

IEA (2020a): ETP Clean Energy Technology Guide. IEA. https://www.iea.org/articles/etp-clean-energy-technology-guide

IEA (2020b): Methane tracker 2020. IEA. https://www.iea.org/reports/methane-tracker-2020/methane-from-oil-gas

IEA (2020c): World Energy Outlook 2020. IEA. https://www.iea.org/events/world-energy-outlook-2020

IEA (2021): Methane Tracker 2021. IEA. https://www.iea.org/reports/methane-tracker-2021

IMF (2019): Putting a Price on Pollution. Finance & Development, 2019, 56(4). https://www.imf.org/external/pubs/ft/fandd/2019/12/the-case-for-carbon-taxation-and-putting-a-price-on-pollution-parry.htm

International Transport Forum (2016): The carbon footprint of global trade: Tackling emissions from international freight transport. International Transport Forum. https://www.itf-oecd.org/sites/default/files/docs/cop-pdf-06.pdf

IPCC (2006): Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF). IPCC. https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html

IRENA (2019a): Renewable Power Generation Costs in 2019. IRENA. https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019

IRENA (2019b): Utility-scale batteries: Innovation Landscape Brief. IRENA. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Utility-scale-batteries_2019.pdf

Indicators for sustainable development under Article 6 of the Paris Agreement

Lako, P. & Tosato, G. (2010): Combined Heat and Power. IEA. https://iea-etsap.org/E-TechDS/PDF/E04-CHP-GS-gct_ADfinal.pdf

Jöhrens, J., Rücker, J., Bergk, F., Schade, W., & Hartwig, J. (2017): Roadmap for an overhead catenary system. Institute for Energy and Environmental Research & M-Five. https://www.ifeu.de/en/project/roadmap-for-an-overhead-catenary-system-for-trucks/

Kachi, A., Mooldijk, S., Dransfeld, B. (2020): Indicators for the promotion of sustainable development in carbon market mechanisms. (Climate Change: 47/2020). https://www.umweltbundesamt.de/publikationen/indicators-for-sustainable-development-under

Kreibich, N., Arens, C., Carvalho, M., Meneses, M., & Sherman, L. (2021): Suitability and Success Factors of Offsets post 2020. Climate Change Series 59/2021, German Environment Agency.

LDC REEI (n.d): Least Developed Countries Renewable Energy and Energy Efficiency Initiative for Sustainable Development. LDC REEEI. http://ldcreeei.org/

Levin, K. & Davis, C. (2019): What does "net-zero emissions" mean? 6 common questions, answered. WRI. https://www.wri.org/blog/2019/09/what-does-net-zero-emissions-mean-6-common-questions-answered

McKinsey & Company (2009): Pathways to a low-carbon economy. McKinsey & Company. https://www.mckinsey.com/~/media/McKinsey/Business Functions/Sustainability/Our Insights/Pathways to a low carbon economy/Pathways to a low carbon economy.pdf

McKinsey & Company (2018): Decarbonization of industrial sectors: The next frontier. McKinsey & Company. https://www.mckinsey.com/~/media/mckinsey/business functions/sustainability/our insights/how industry can move toward a low carbon future/decarbonization-of-industrial-sectors-the-next-frontier.pdf

McKinsey & Company (2020a): The future is now: How oil and gas companies can decarbonize. McKinsey & Company. https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-future-is-now-how-oil-and-gas-companies-can-decarbonize

McKinsey & Company (2020b): Driving CO2 emissions to zero (and beyond) with carbon capture, use, and storage. McKinsey & Company. https://www.mckinsey.com/business-functions/sustainability/our-insights/driving-co2-emissions-to-zero-and-beyond-with-carbon-

National Geographic (n.d.): Distribution of fossil fuels. National Geographic. https://www.nationalgeographic.org/encyclopedia/distribution-fossil-fuels/

Partnership on Transparency in the Paris Agreement (2018): SDG Climate Action Nexus tool (SCAN-tool): Interactive online dashboard available. Partnership on Transparency in the Paris Agreement. https://www.transparency-partnership.net/documents-tools/sdg-climate-action-nexus-tool-scan-tool-interactive-online-dashboard-available

Rennaud, J.P., Ruitenbeek, J., & Tennigkeit, T. (2013): Challenges of Community-Forestry Based Carbon Projects: Process, Participation, Performance. The Journal of field actions (7). https://journals.openedition.org/factsreports/2134#tocto1n1

Leard, B.; Linn, J.; Cleary, K.(2020): Carbon pricing 202: Pricing carbon in the transportation sector. Resources for the Future. https://www.rff.org/publications/explainers/carbon-pricing-202-pricing-carbon-transportation-sector/

Lehmann, M (2018): eHighway SoCal: Final report. Siemens. https://cleanairactionplan.org/documents/siemens-scaqmd-catenary-port-truck-final-report-2018.pdf/

Stiglitz, J. & Stern, N. (2017): Report of the high-level commission on carbon prices. Carbon Pricing Leadership Coalition. https://static1.squarespace.com/static/54ff9c5ce4b0a53decccfb4c/t/59b7f2409f8dce5316811916/1505227332748/CarbonPricing_FullReport.pdf

Transport & Environment (2013): Consultation reply: Road transport in the EU ETS – why it is a bad idea. Transport & Environment. https://ec.europa.eu/clima/sites/clima/files/docs/0017/organisations/t_and_e_en.pdf

Trove Research and UCL (2021): Future demand, supply and prices for voluntary cabron credits – keeping the balance. Trove Research and UCL. https://trove-research.com/wp-content/uploads/2021/06/Trove-Research-Carbon-Credit-Demand-Supply-and-Prices-1-June-2021.pdf

UN (n.d): Energy access and main challenges in the LDCs. UN. https://www.un.org/ldcportal/energy-access-and-main-challenges-in-the-ldcs/

Warnecke, C., Höhne, N., Tewari, R., Day, T., & Kachi, A. (2018): Opportunities and safeguards for ambition raising through Article 6—The perspective of countries transferring mitigation outcomes. NewClimate Institute. https://newclimate.org/2018/05/09/opportunities-and-safeguards-for-ambition-raising-through-article-6/

World Bank (n.d.): Global Gas Flaring Tracker Data. World Bank. Accessed on 20 August 2021. https://www.ggfrdata.org/.

World Bank (2020): State and Trends of Carbon Pricing 2020 report. World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/33809/9781464815867.pdf?sequence=4&isAllowed=y

World Bank (2021): Global Gas Flaring Tracker Report. World Bank. https://thedocs.worldbank.org/en/doc/1f7221545bf1b7c89b850dd85cb409b0-0400072021/original/WB-GGFR-Report-Design-05a.pdf