SHIFTING VOLUNTARY CLIMATE FINANCE TOWARDS THE HIGH-HANGING FRUIT OF CLIMATE ACTION

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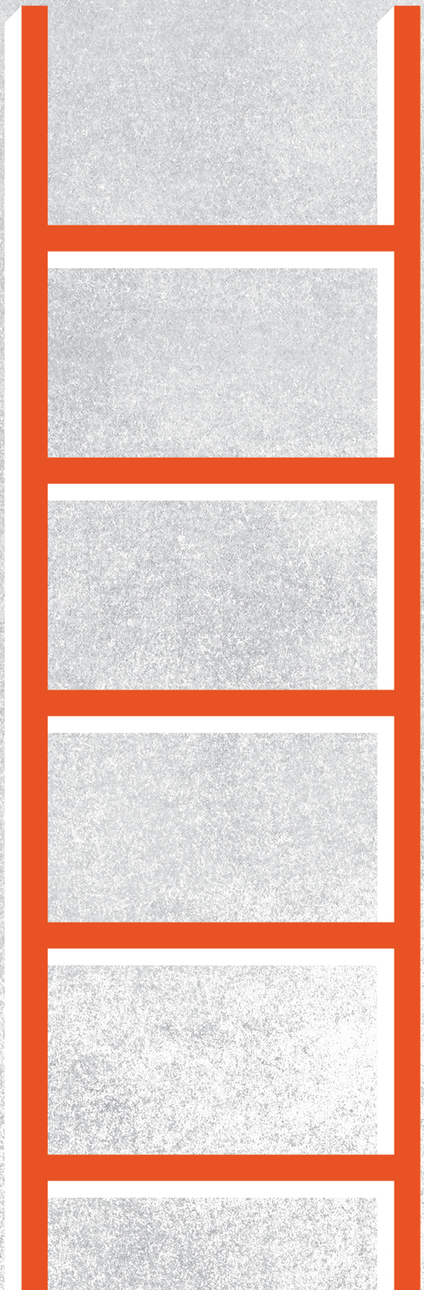

SHIFTING VOLUNTARY CLIMATE FINANCE TOWARDS THE HIGH-HANGING FRUIT OF CLIMATE ACTION

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SUMMARY

The high-hanging fruit of mitigation potential refers to the technologies and measures to decarbonise emission sources that remain otherwise entirely inaccessible to host country governments in the near- and medium-term future, on account of extraordinary costs or other insurmountable barriers that cannot reasonably be overcome.

HIGH-HANGING FRUIT MITIGATION PROJECTS CAN SUPPORT GLOBAL AMBITION RAISING THROUGH THE IDENTIFICATION AND IMPLEMENTATION OF SOLUTIONS FOR THE HARDEST TO ABATE EMISSION SOURCES. (→ SECTION A1.1)

The objectives of the Paris Agreement require a rapid reduction in emissions from all sectors towards net-negative emissions, but the availability of technologies for deep decarbonisation remains very limited for approximately one third of global GHG emission sources.

The development of new solutions for these emission sources is an urgent issue, but developments are slow or in some cases even not foreseeable. Voluntary climate finance is especially well suited to address these innovative and emerging technologies through high-hanging fruit projects.

FOR CARBON CREDITING MECHANISMS USED FOR COMPLIANCE PURPOSES OR VOLUNTARY OFFSETTING CLAIMS, HIGH-HANGING FRUIT PROJECTS REPRESENT THE ONLY SOLUTION TO ENSURE THAT OVERALL CLIMATE CHANGE MITIGATION AMBITION CAN BE ENHANCED RATHER THAN COMPROMISED. (→ SECTION A1.2)

The concept of additionality is intended to demonstrate that the GHG abatement activity of a project supported through carbon crediting mechanisms would not have happened otherwise, but the concept is outdated and applied inconsistently.

The global governance framework of the Paris Agreement represents a different context from the Kyoto-era, and requires the concept of additionality to be reconsidered. Projects should be sufficiently ambitious that they avoid presenting any conflict with the host country's own ambition. Otherwise, the prospect of carbon credit revenue associated with carbon crediting mechanisms for voluntary offsetting claims or compliance purposes may present a perverse incentive for countries to limit their climate change mitigation ambition. The costs of using such mechanisms must also be high enough to send a signal to the buyer for further decarbonisation, to avoid distraction and delay to decarbonisation efforts.

While carbon crediting mechanisms that are used for compliance or offsetting claims should be restricted to high-hanging fruit projects, such mechanisms do not necessarily represent the best option for channelling finance to those projects. The case studies in → **Section B** of this report demonstrate that carbon crediting mechanisms are not a practical option for some high-hanging fruit technologies and measures that are still in earlier stages of development or entail significant risks. Such projects do not lend themselves to quantifiable mitigation outcomes that can be predicted ex-ante.

The suitability of carbon dioxide removals for carbon crediting mechanisms is also highly contentious, due to the non-permanence, scarcity and environmental costs associated with carbon dioxide removals, which means that those outcomes cannot be considered a fungible equivalent to emission reductions.

CLIMATE CONTRIBUTIONS NOT ASSOCIATED WITH OFFSETTING CLAIMS MAY BE THE MOST APPROPRIATE AND CONSTRUCTIVE CHANNEL FOR FINANCIAL SUPPORT TO SOME HIGH-HANGING FRUIT MITIGATION PROJECTS. (→ SECTION A1.3)

Climate contributions offer a more transparent and constructive alternative channel for supporting such projects. Climate contributions reflect finance provided by an organisation to support climate action beyond its own value chain, without claiming to offset, or neutralise, any actual emissions. Under this construct, the mitigation outcomes of support projects are owned by the actors supported and the host country they operate in, rather than transferred to the support provider for use towards an offsetting claim or the achievement of their own emission reduction targets. Accordingly, this can provide support for reaching and ratcheting up host countries' GHG emission reduction targets, rather than conflicting with them.

Since climate contributions are not used towards offsetting claims or the targets of the support provider, support provided through this means can reach a broader range of project types, since it is not dependent on the quantification of outcomes in terms of emission reduction units. High-hanging fruit projects represent a very attractive option for ambitious support providers who are interested to be at the forefront of innovation.

PROJECTS CAN BE IDENTIFIED AS HIGH-HANGING FRUITS ON ACCOUNT OF THEIR EXTRAORDINARILY HIGH COSTS, OR IF THEY INTRODUCE TRULY FIRST-OF-KIND TECHNOLOGIES. PROJECTS MUST BE COMPATIBLE WITH NET-ZERO EMISSION TECHNOLOGIES AND TRANSITIONS. (→ SECTION A2)

The accessibility of a climate change mitigation project can be considered as a spectrum of technology readiness and cost **(see → Figure S1)**. That spectrum contains high- and low-hanging fruit projects, either side of a significant grey area.

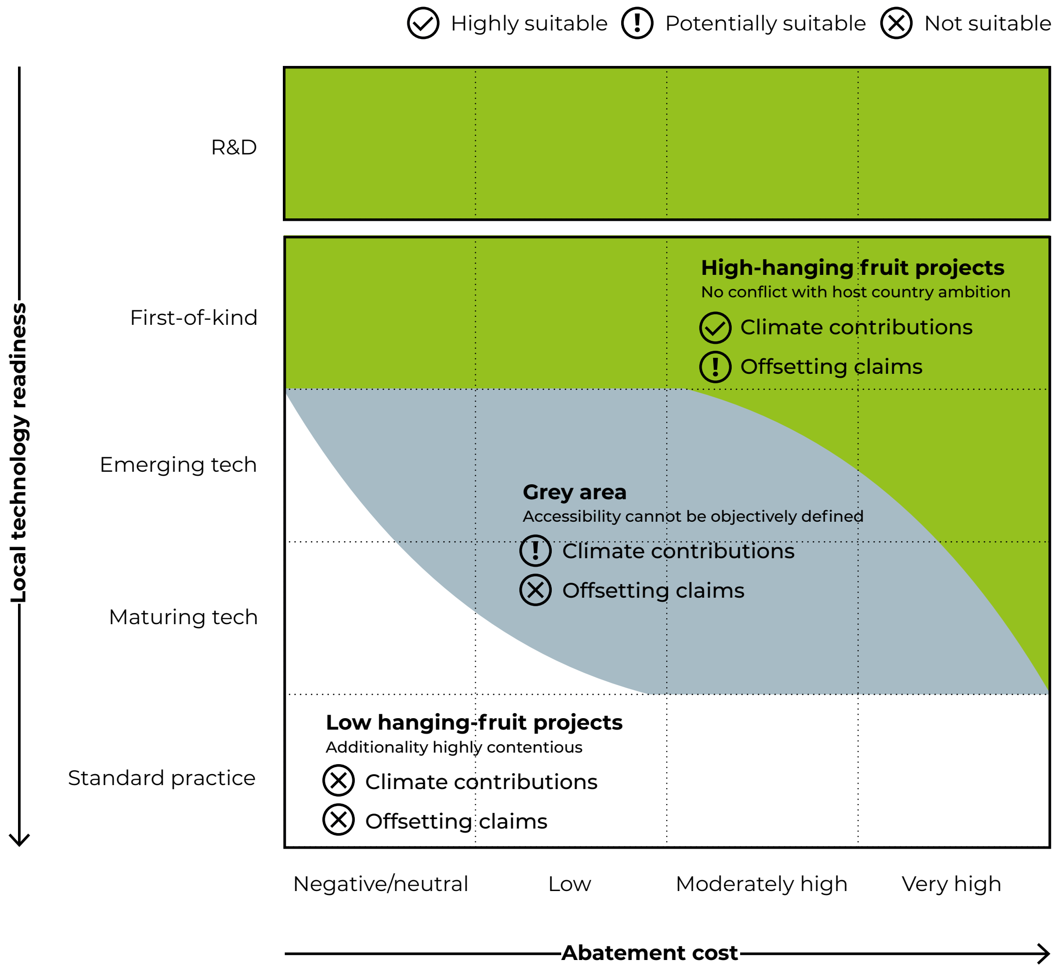

Figure S1

Spectrum of mitigation project inaccessibility

Carbon credits for offsetting claims and compliance purposes must be restricted to the niche of projects that can be objectively categorised as high-hanging fruits. For climate contributions that are not associated with neutralisation claims, accessibility is still a relevant consideration for additionality of support, but an objective guarantee of project 'inaccessibility' is less critical: the 'grey area' may be reasonable for climate contributions and will contain projects very worthy of support.

Technologies that can be demonstrated to be truly first-of-kind are unlikely to present a significant conflict with host country ambition. The geographical boundary of the definition for "first-of-kind" should be at the level of country groupings or global subregions, rather than the national or subnational level, to avoid rewarding laggards.

A demonstration of extraordinarily high marginal abatement costs can provide an indication of the relative inaccessibility of technologies and measures. For projects with readily quantifiable mitigation outcomes, this could be demonstrated by aiming within the range of scientific estimates for a Paris-compatible carbon price signal: the full range of values identified from the literature review in the IPCC Special Report on Global Warming of 1.5 °C spans from USD 135-6,050/ tCO_2e in 2030 for compatibility with limiting warming to 1.5°C (IPCC, 2018).

An international "allow list" of emerging, immature and expensive technologies could also be a pragmatic approach to demonstrate project inaccessibility, but depends on strict definitions **(→ Section A2.2)**.

Regardless of the means for demonstrating the inaccessibility of a project, projects can only make a constructive contribution to climate ambition if they are compatible with other necessary net-zero emission technologies and transitions, to avoid lock-in to technologies and practices that are not aligned with the long-term objectives of the Paris Agreement.

POTENTIAL HIGH-HANGING FRUIT PROJECTS ARE IDENTIFIED FOR AGRICULTURE, HEAVY-DUTY TRANSPORT AND BUILDING HEAT IN COLD CLIMATES. (→ SECTION B)

Section B of this report identifies for illustrative purposes potential high-hanging fruit technologies and measures from specific emission sources:

- **Building heat in Mongolia (→ Section B4):** High-hanging fruit projects can demonstrate the feasibility of available solutions for zero-emission heat in severely cold temperatures **(e.g. in Mongolia, → Section B4)**. **Solar assisted air-source or ground-source heat pumps (building-scale)** can provide reliable and efficient year-round heating since new technological developments have overcome traditional barriers, but upfront capital expenditures are high and there is limited experience with the technologies in Mongolia. **Retrofit of district heating networks for low temperature supply** is necessary to integrate renewable energy technologies into the system, but low temperature networks remain in limited use worldwide. **District scale heat pumps and solar thermal systems** can be a highly efficient solution, but such large-scale systems are yet to be tested in the Mongolian context.
- **Transport in Indonesia (→ Section B5):** The decarbonisation of Indonesia's transport sector requires centrally planned infrastructure developments for modal shift and electrification, but high-hanging fruit demonstration projects can play an important role to kick-start the uptake of technologies. The **electrification of the bus fleet** can decarbonise the passenger transport sector on inner-city routes, and potentially short distance inter-city routes. Electric buses have been

demonstrated to be a feasible technology for inner-city transport in the Indonesian context, although costs remain high and they remain in the early stages of adoption. The **electrification of trucks** could significantly reduce the emissions from fuel combustion in the Indonesian freight transport sector, which is mostly road based and dependent on old, emission-intensive trucks. The **electrification of small and medium-sized watercraft** for passengers and freight together with the expansion and decarbonisation of port and/or community scale renewable electricity generation and charging infrastructure can reduce the emissions associated with domestic maritime transport. With hundreds of formal ferry connections, many of which span only short distances, and hundreds of thousands of informal community scale maritime transport, opportunities may exist for demonstration projects of various scales.

→ **Agriculture in Georgia (→ Section B6):** High-hanging fruit projects can support the emergence of new technologies and measures for deep emission reductions in croplands. **Electrified farm machinery** can decarbonise agricultural energy but is not yet available on the Georgian market. **Soil and plant microbiome technologies** can enhance carbon sequestration and reduce nitrous oxide emissions, but the import of microbiome inputs is expensive and these are not yet adapted to local crops. **New perennial grain** crops can enhance carbon sequestration and decrease soil erosion, but research and development is needed to adapt these crops to the Georgian context.

IT IS HIGHLY CHALLENGING TO IDENTIFY HIGH-HANGING FRUIT PROJECTS TODAY. A PIPELINE OF PROJECTS IS NOT READILY AVAILABLE AND WILL REQUIRE INTERVENTIONS TO DEVELOP. (→ SECTION A3)

We propose the following recommendations for targeted interventions to support the development of a pipeline for high-hanging fruit projects, and to channel voluntary climate finance with more transparency and integrity:

→ **Redefining additionality:** Since market mechanisms will always search for the most cost-effective option within given parameters, it is only feasible for market mechanisms to play a role in financing the high-hanging fruit of climate change mitigation potential if those given parameters are adjusted, such that the definition of project "additionality" includes a demonstration of project inaccessibility **(→ Section A2.2)**.

→ **Introducing labels for high-hanging fruit projects:** Given the currently very limited pipeline of high-hanging fruit projects that could be implemented in the immediate future, some carbon crediting standards and registries may be reluctant to immediately adopt a sufficient definition of additionality. A labelling mechanism for high-hanging fruit projects to clearly demonstrate the difference between "possible" and "guaranteed" additionality should be a minimum for ambitious standards and registries.

- **Establishing funds for channelling climate contributions:** There is an important role for either new or established initiatives to channel climate contributions towards projects that have not been reached by existing market mechanisms, such as less mature technologies or projects with less readily quantifiable outcomes.
- **Corporate leadership:** Given the limited readiness of the market to present a compelling project pipeline, companies that are interested to support high-hanging fruit projects to demonstrate their climate leadership will need to play a driving role, by directly identifying projects, or contributing to initiatives that seek to do so.
- **Proactive intermediaries:** Established consultants and intermediaries that are already working with companies on their climate strategies and the channelling of their voluntary climate finance are in a pivotal position to accelerate the evolution of voluntary climate finance flows to high-hanging fruit projects. In some regards, the sustainability of their own business models also depends on this. These consultants and intermediaries should play a proactive role in looking for and generating project ideas for high-hanging fruit projects, as well as raising awareness amongst their corporate clients on the relevance – or necessity – for supporting such projects

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1.1 THE IMPORTANCE OF THE HIGH-HANGING FRUIT OF CLIMATE ACTION

The high-hanging fruit of mitigation potential refers to the technologies and measures to decarbonise emission sources that remain otherwise entirely inaccessible to host country governments in the near- and medium-term future, on account of limited maturity, extraordinary costs or other insurmountable barriers that cannot reasonably be overcome.

THE OBJECTIVES OF THE PARIS AGREEMENT REQUIRE A RAPID REDUCTION IN EMISSIONS FROM ALL SECTORS TOWARDS NET-NEGATIVE EMISSIONS, BUT THE AVAILABILITY OF TECHNOLOGIES FOR DEEP DECARBONISATION REMAINS VERY LIMITED FOR SOME GHG EMISSION SOURCES.

With the objectives of the Paris Agreement, greenhouse gas (GHG) emissions need to be reduced at speed, in all countries and in all sectors. The 1.5°C limit requires a reduction in global GHG emissions of approximately 43% from 2019 levels by 2030, towards a state of net-zero global CO_2 emissions by around 2050, net-zero of emissions of all greenhouse gases by around 2060 to 2070, and net-negative emissions thereafter (IPCC, 2022).

→ **Figure 1** provides an illustrative overview of technology availability for deep decarbonisation, for different sectors and emission sources, showing that the level of readiness to transition to the necessary decarbonisation trajectories in many sectors remains limited. For heavy duty transport, industrial energy, industrial process emissions, building heat in cold climates and agriculture, the availability of technologies for deep or full decarbonisation remains very limited, or the technologies for deep decarbonisation are still emerging and entail higher uncertainty. The figure indicates that these emission sources account for a significant proportion of global GHG emissions.

Although 1.5 °C trajectories foresee a role for carbon dioxide removal technologies to neutralise some residual emissions from the hardest to abate emission sources (IPCC, 2022), the potential for carbon dioxide removal technologies is very limited (Fuss et al., 2018; Hepburn et al., 2019; Roe et al., 2019) and there will still be a need for the deep reduction of emissions from these emission sources.

THE DEVELOPMENT OF NEW SOLUTIONS FOR THESE EMISSION SOURCES IS AN URGENT ISSUE, BUT DEVELOPMENTS ARE SLOW OR IN SOME CASES EVEN NOT FORESEEABLE.

To maximise the amount of climate ambition that can be achieved with available resources, governments and many other actors tend to focus on the most reliable and cost-efficient options for marginal further emission reductions. Currently, the vast majority of investment into GHG emission reduction measures worldwide flows into the implementation and scale up of readily available technologies in sectors with more accessible mitigation potential, such as power supply, energy efficiency measures and forestry-related projects. An estimated USD 571 billion of climate finance flowed to GHG emission reduction projects per year in 2019 and 2020, from public and private finance sources, with an estimated 91% of this finance going to solar PV and onshore wind (Buchner et al., 2021) Renewable energy, energy efficiency and forestry-related projects account for approximately 93% of credit issuance from the carbon crediting standards serving the voluntary markets in 2021 (Donofrio et al., 2022).

Financing the low hanging fruit of mitigation potential may be a logical approach for individual actors to continually achieve marginally increases on their climate ambition, and these sectors remain in need of a significant upscale of investment to reach necessary decarbonisation trajectories. But the objective to transition to net-zero and eventually net-negative emissions at the global level also depends on attention and investment into the emission sources for which solutions do not exist or remain too expensive.

The pace at which solutions for these emission sources is being identified and maturing is possibly not aligned with the urgency of their development. Of the potentially emerging solutions identified for some of these emission sources **(see → Section B)**, we recognise that the pace of development for these technologies is slow. In some cases, technologies and measures with theoretically proven potential are not significantly more mature in relevant markets than they were many years ago. For some other emission sources, there remains a complete lack of technologies and measures that even have the technical potential to deeply decarbonise those emission sources.

The emergence, maturation and widespread implementation of new technologies is a process that can take many years – even decades – and not something that can wait until the point at which those technologies and measures would represent the next most cost-effective marginal abatement option. There is also an urgency of reckoning for the emission sources for which new technological solutions may not be reliably foreseeable and for which climate objectives will depend on much broader transitions for societal behaviours. Such systematic transitions – where they are necessary – cannot be left to the last moment.

VOLUNTARY CLIMATE FINANCE IS ESPECIALLY WELL SUITED TO SUPPORT GLOBAL AMBITION RAISING THROUGH THE IDENTIFICATION AND IMPLEMENTATION OF INNOVATIVE AND EMERGING SOLUTIONS FOR THE HARDEST TO ABATE EMISSION SOURCES.

Since carbon credit markets have traditionally favoured the low hanging fruit of mitigation potential, very little voluntary climate finance flows to the identification of solutions for these more complex emission sources. Likewise, some immature and exploratory technologies represent too high a risk to be addressed through private capital, either as direct investment or through carbon crediting mechanisms.

This limited flow of finance is in stark contrast to the relevance of such projects for voluntary climate finance providers. The potentially emerging solutions that we identify for some of the hardest to abate emission sources **(see → Section B)** indicate a relevant role for voluntary project finance to advance many of these opportunities, such as through demonstration projects for emerging technologies or contributions to research that is not already being spearheaded through private sector interests.

Innovative and emerging technologies lend themselves well to project-based finance, which voluntary climate finance providers often prefer due to the tangibility and boundaries of a project intervention. High-hanging fruit projects can also portray a positive image regarding the climate ambition of those providing finance to them, delivering on a key objective for companies that are keen to demonstrate their ambition to investors and consumers. If the narrative of voluntary climate finance storytelling shifts to focus more on the innovative and exploratory nature of the projects supported, this could create a race-to-the-top for ambition and innovation from voluntary project finance.

EMISSION SOURCES FOR WHICH DEEP DECARBONISATION TECHNOLOGIES ARE MORE READILY AVAILABLE MAY ALSO STILL NEED SUPPORT, BUT IT MAY BE MORE CHALLENGING TO IDENTIFY TRULY HIGH-HANGING FRUIT PROJECTS FOR THESE EMISSION SOURCES.

→ Figure 1 also indicates that technologies are theoretically available for many sources of global emissions. Renewable energy technologies have matured to a point where they represent a comparably accessible measure for the deep decarbonisation of electricity generation in many countries. By extension, sources of energy demand for which electrification technologies are becoming more competitive may also be considered emission sources for which their decarbonisation is comparably achievable.

This does not mean that national governments necessarily have the available means to unilaterally decarbonise their electricity grids over the short term. Nor does it mean that they have the necessary resources to unilaterally electrify all areas of transportation and industry for which it is potentially feasible and attractive to do so. Aside from relevant factors such as private interest lobbying and political will, the energy transition also faces enormous technical and economic challenges related to scale of infrastructural overhaul that is required and the capital expenditures that it entails.

In very many contexts, project-based finance that is used to implement mature technologies can still support national governments to accelerate transitions and to increase their climate change mitigation ambition. These may be very worthwhile support endeavours. However, the comparable accessibility of these technologies differentiates them from those that can be considered truly inaccessible high-hanging fruits, when considering additionality in the context not only of existing government policies and plans but also in the context of potential ambition raising. These projects may well be worthy of support, but they are not necessarily high-hanging fruit projects that can provide a suitable guarantee of additionality for offsetting or compliance claims **(see → Section A1.2)**.

THE ACCESSIBILITY OF TECHNOLOGIES AND MEASURES IS HIGHLY DEPENDENT ON THE CONTEXT; HIGH-HANGING FRUIT PROJECTS COULD BE IDENTIFIED FOR MOST EMISSION SOURCES.

The presentation of emission sources in → **Figure 1** provides only an illustrative indication of the areas most lacking in technology availability; this does not constitute an absolute indication of what might constitute a high-hanging fruit mitigation measure and what not.

There is still the potential – and the need – for the identification of highly innovative technologies for most emission sources. For example, although several technologies for renewable power generation are relatively mature, the decarbonisation of the electricity system will also depend on less mature technical solutions for storage, load balancing and transmission; in some contexts such measures would be highly innovative. For some emission sources, technology availability and maturity also varies significantly between regions.

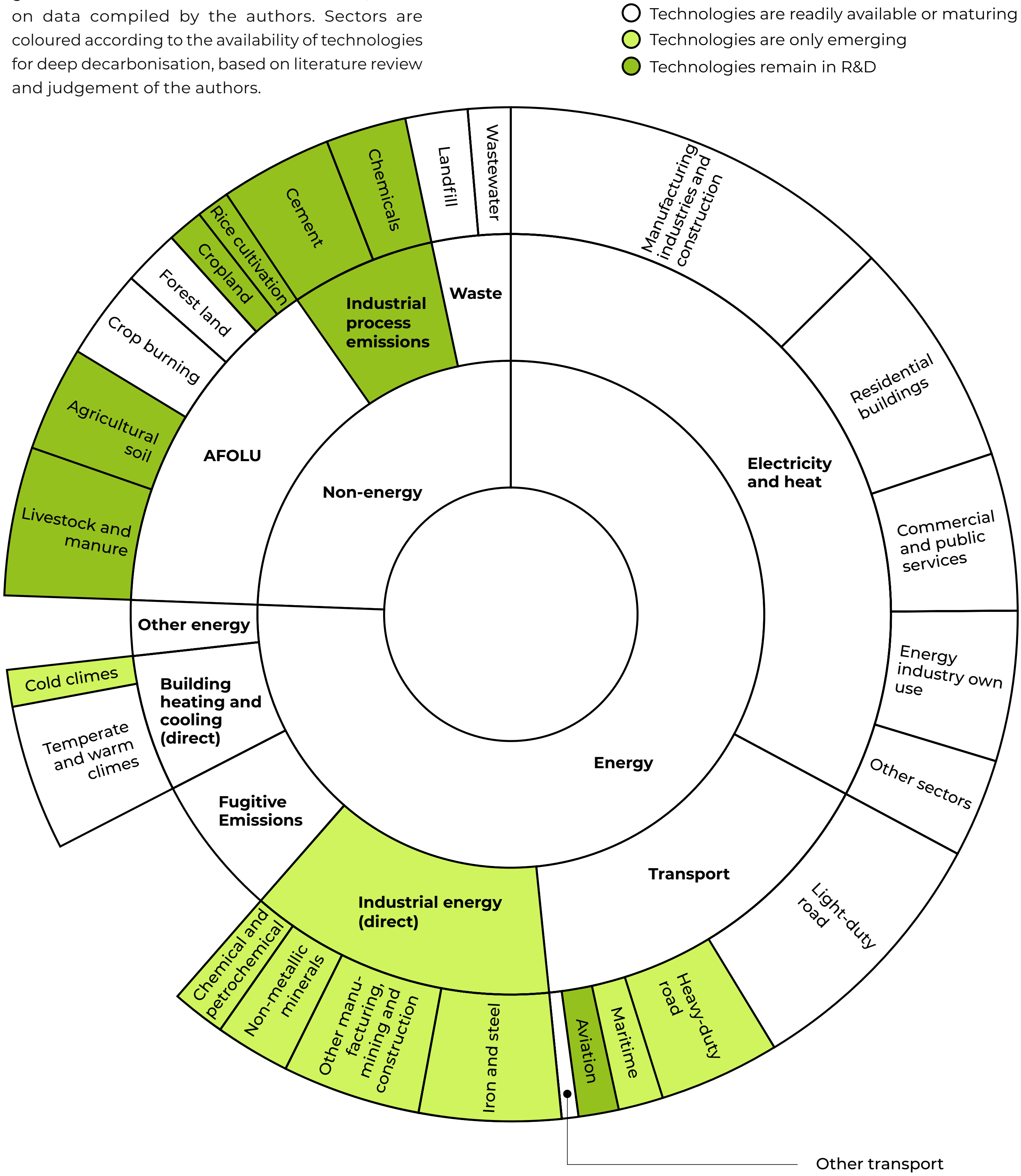
Likewise, not all measures for the decarbonisation of complex emission sources can be considered high-hanging fruit. For some emission sources, technologies for shallow or moderate emission reductions may be readily available and mature, even when there remains a lack of technological options and a need for innovative solutions for deep decarbonisation.

Accordingly, the extent to which a mitigation project represents the high-hanging fruit of mitigation potential depends on the context, as demonstrated by the illustrative case studies in → **Section B**.

Figure 1

Illustrative overview of technology availability for deep decarbonisation

The diagram presents the approximate spread of global GHG emissions across sectors in 2019, based on data compiled by the authors. Sectors are coloured according to the availability of technologies for deep decarbonisation, based on literature review and judgement of the authors.



1.2 CARBON CREDITING MECHANISMS USED FOR OFFSETTING CLAIMS

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Companies, governments and other actors make an offsetting claim when they assert that unabated GHG emissions within their value chain are 'neutralised', 'netted-out', 'offset', 'inset' or 'counterbalanced' (among other terminologies) through other emission reduction activities or carbon dioxide removals – inside or outside of their value chain.

THE CONCEPT OF ADDITIONALITY IS INTENDED TO DEMONSTRATE THAT THE GHG ABATEMENT ACTIVITY OF A PROJECT SUPPORTED THROUGH CARBON CREDITING MECHANISMS WOULD NOT HAVE HAPPENED OTHERWISE, BUT THE CONCEPT IS OUTDATED AND APPLIED INCONSISTENTLY.

Conviction on the additionality of a carbon crediting activity is fundamental to the simple logic of an offsetting or compliance claim: an actor should not be able to claim to have offset their emissions if they cannot be sure that their carbon credit procurement leads to an equivalent climate impact to the direct reduction of the actor's own emissions.

For most existing carbon crediting standards, additionality is assessed to demonstrate a project's environmental integrity before that project is registered to the standard. Additionality is defined in a similar way by most of the existing carbon offset crediting standards serving both compliance and voluntary carbon markets, although the stringency of the methods for operationalising the concept vary significantly between standards.

In the context of the Clean Development Mechanism (CDM), the UNFCCC defined additionality to be "the effect of the CDM project activity or CPA to reduce anthropogenic GHG emissions below the level that would have occurred in the absence of the CDM project activity or CPA" (UNFCCC, 2012a). In practice, this definition is operationalised through the CDM Methodological tool for the demonstration and assessment of additionality (UNFCCC, 2012b). The challenges of operationalising this seemingly straightforward definition are demonstrated by the fact that eleven updates to the methodological tool were published by the CDM Executive Board between Version 1 in 2004 and Version 7.0.0 in 2012, and criticism continued nonetheless.

Although the context of the global governance framework for climate change has changed significantly in the past years, most notably with the ratification and coming into force of the Paris Agreement, there has been no meaningful development of the additionality concept during the past decade. The Carbon Credit Quality initiative – launched in 2022 and recognised as having one of the most thorough independent methodologies for the assessment of carbon credit quality – adopts an approach for additionality assessment that largely aligns with CDM methodological tool, without proposing significant advances on that approach.

THE GLOBAL GOVERNANCE FRAMEWORK OF THE PARIS AGREEMENT REPRESENTS A DIFFERENT CONTEXT FROM THE KYOTO-ERA, AND REQUIRES THE CONCEPT OF ADDITIONALITY TO BE RECONSIDERED.

As one of the key conditions for the environmental integrity of carbon crediting projects, additionality remains a key concept for carbon crediting mechanisms in the context of the post-2020 global climate governance framework of the Paris Agreement, but there is not an authoritative consensus of what additionality means in this context.

The rules, modalities and procedures for the mechanism established by Article 6, paragraph 4, of the Paris Agreement, introduces additionality through the following clauses:

Paragraph 38 Additionality shall be demonstrated using a robust assessment that shows the activity would not have occurred in the absence of the incentives from the mechanism, taking into account all relevant national policies, including legislation, and representing mitigation that exceeds any mitigation that is required by law or regulation, and taking a conservative approach that avoids locking in levels of emissions, technologies or carbon-intensive practices incompatible with paragraph 33 above.

– FCCC/PA/CMA/2021/L.19, Annex Para 38

Paragraph 33 The clause includes, among other criteria, the requirement to “align to the long-term temperature goal of the Paris Agreement”. We understand that this implies compatibility with net-zero emission technologies and systems across all sectors by mid-century.

According to these clauses, the demonstration of additionality for carbon crediting project eligibility under the Paris Agreement should require – at a minimum – compliance with the following criteria:

- The activity is not required or likely to have been implemented due to national policies or legislation, and would not have occurred in the absence of the incentives of the mechanism.
- The activity does not lock in levels of emissions, technologies or carbon-intensive practices that are incompatible with the achievement of net-zero emissions across all sectors by 2050.

At a first glance, these criteria may look similar to those required for the demonstration of additionality under the Kyoto-era flexibility mechanisms, but on closer inspection this is not the case: an assessment of what might have occurred in the absence of the incentives of the mechanism needs to consider the current context, which differs from the context of the Kyoto-era.

In the Kyoto-era, carbon crediting mechanisms were established as a flexibility mechanism for countries with emission reduction targets to offset their emissions in countries without emission reduction targets. **Under the Paris Agreement**, all countries are bound to set and regularly revise own Nationally Determined Contributions that should reflect their maximum possible ambition and move towards a common objective of achieving net-zero emissions by mid-century. Towards these objectives, the Paris Agreement's Article 6 mechanisms are established explicitly as ambition raising mechanisms (UNFCCC, 2015 Article 6.1).

Under this new context, an assessment of what might have occurred in the absence of the incentives of the mechanism needs to ensure – first-and-foremost – that existing ambition mechanisms under the Paris Agreement governance framework are not undermined. The potential for carbon crediting mechanisms used for offsetting or compliance purposes to compromise climate ambition mechanisms is explored in the next section.

IN THE CONTEXT OF THE PARIS AGREEMENT, HIGH-HANGING FRUIT MITIGATION PROJECTS REPRESENT THE ONLY SOLUTION TO ENSURE THAT CREDITING MECHANISMS USED FOR OFFSETTING OR COMPLIANCE CLAIMS ENHANCE RATHER THAN COMPROMISE OVERALL CLIMATE CHANGE MITIGATION AMBITION.

The context of today's global governance framework for the mitigation of climate change bears little resemblance to that of previous decades, when major carbon crediting mechanisms were first conceptualised and implemented. While the majority of countries were not required to commit to formal emission reduction targets under the 1992 Kyoto Protocol, all Parties to the 2015 Paris Agreement have put forward climate change mitigation commitments in the form of Nationally Determined Contributions (NDCs) and have committed to regularly ratchet up the ambition of those commitments. Through civic action and the increasing evidence base on the urgency of the climate crisis, climate change has been elevated to one of the primary concerns of voters, investors and consumers. The degree of pressure that major companies face today from governments, investors and consumers, means that corporate climate action can no longer be considered voluntary in the way that it was just one decade ago.

These differences lead to the reality that the original design of carbon crediting mechanisms for offsetting and compliance claims is not necessarily still fit for the purpose of increasing global climate change mitigation ambition. Rather, such mechanisms now carry potential to potentially compromise overall climate change mitigation ambition, by providing perverse incentives to restrict ambition for climate change mitigation action, both on the demand and supply side of the market:

→ **Demand-side ambition pitfall**

The costs of using carbon crediting mechanisms for offsetting or compliance purposes must be high enough to send a signal to the buyer for further decarbonisation, to avoid distraction and delay to decarbonisation efforts. The prices of carbon credits from high-hanging fruit projects will mitigate the risk that the use of crediting mechanisms is seen an attractive alternative to emission reductions.

The objectives of the Paris Agreement require a reduction in global GHG emissions towards a state of net-zero emissions by mid-century, and net-negative emissions thereafter (IPCC, 2022). This means the full decarbonisation of all economies, a highly challenging task that depends on cooperation and transparent dialogue. Carbon neutrality claims that are delivered through carbon crediting mechanisms can distract from the urgency of action required, leading to delayed action. This can result in continued investments and consequently increased lock-in to carbon-intensive infrastructure. The climate strategies of nations, subnational governments, industries, companies and individuals, need to first and foremost incentivise and facilitate the reduction of their own emissions.

The increased pressure for climate action exerted on companies and governments by consumers, citizens and investor is an important driver towards deeper levels of decarbonisation. But the use of carbon credits for offsetting claims can be a response to this pressure, and in some cases it may be a substitute for climate action.

The abatement costs of projects supported in other countries should be high enough to send a signal for the potential carbon credit buyer to significantly reduce its own emissions, rather than providing an avenue for the continuation of business as usual. For orientation, the High-Level Commission on Carbon Prices (2017) found a carbon price range of USD 40-80/tCO_2e in 2020 to be consistent with the Paris Agreement's "well below 2 ˚ C" goal, provided a supportive policy environment is in place, rising to USD 50-100/tCO_2e in 2030. The IPCC Special Report on Global Warming of 1.5 °C (IPCC, 2018) found with high confidence that the global average discounted marginal abatement costs for limiting warming to 1.5°C were likely about 3–4 times higher compared to the costs for limiting warming to below 2°C. The full range of values identified from the literature review in the IPCC Special Report included a range of USD 15-220/ tCO_2e in 2030 for compatibility with limiting warming to below 2°C, compared with a range of USD 135-6,050/ tCO_2e in 2030 for compatibility with limiting warming to below 1.5°C (IPCC, 2018, p. 152). By comparison, the average credit price for voluntary carbon market transactions in 2021 was approximately USD 4 (Donofrio et al., 2022). This indicates the need for quite a radical transformation in the type and accessibility of mitigation project that is addressed through carbon crediting mechanisms that are used for offsetting and compliance purposes.

Credit prices for high-hanging fruit projects are likely to be significantly higher than those available on carbon credit markets today. Making offsetting claims through high-hanging fruit projects may remain an attractive option for countries and companies to claim the neutralisation of their emissions in the immediate-term until they have been able to implement sufficient mitigation measures of their own, but offsetting at these prices would likely no longer represent an attractive alternative to those own mitigation measures over the medium-term, and would be far less likely to lead to delayed action in this regard.

→ **Supply-side ambition pitfall**

Carbon crediting projects used for offsetting or compliance purposes should be sufficiently ambitious that they avoid presenting any conflict with the host country's own ambition. Otherwise, the prospect of carbon credit revenue may present a perverse incentive for countries to limit their climate change mitigation ambition. Carbon credits from high-hanging fruit projects can support rather than conflict with host-country ambition.

The Paris Agreement requires all countries to set self-determined emission reduction targets (Nationally Determined Contributions – NDCs), which are to be revised at least every five years to reflect each country's highest possible ambition level.

Emission reduction credits that are sold for offsetting or compliance purposes should not be counted towards the achievement of a host country's GHG emission reduction target, to avoid that those emission reductions are double counted **(see → Box 1)**. As such, the prospect of potential revenues from emission reduction credits associated with offsetting claims may present countries with a perverse incentive to restrict the extent to which they ratchet-up the ambition of their unilateral action during NDC revision cycles. To maximise the amount of foreign investment, countries may limit their own national GHG emission reduction targets so that more of their mitigation potential can be tapped by international carbon market mechanisms **(see → Box 2)**.

This perverse incentive issue is not as trivial as overcoming individual cases of opportunism. Rather, it may present a substantial difficulty for governments that would otherwise strive for ambitious climate policy. Pilot programmes for bilateral cooperation under Article 6.2 have demonstrated that countries may not be in a position to reject the advances of richer nations who offer money in return for the mitigation outcomes of relatively accessible measures (NewClimate Institute, 2021). Recipient nations of some pilot programmes for bilateral cooperation may struggle to explain how the proposed support is indeed additional to their current plans; there is a significant risk that those countries, and other countries observing this process, may conclude that they should be more conservative about what level of climate change mitigation ambition they commit to in the future, as well as the level of detail that they present alongside those commitments.

If demonstration of additionality compared simply to existing host country policy remains the bar for carbon crediting project eligibility, then one should expect a race to the bottom in ambition and transparency from other nations or subnational regions that see any significant potential for the sale of carbon credits that are authorised for international transfer. Even governments with the most ambitious climate agendas will face even more difficulties to square their envisaged plans with political opponents or sceptical lobby groups who would have new arguments for curtailing ambition.

The only way to avoid this perverse incentive and to support additional ambition in parallel, is to exclusively support the more accessible measures though other sources of support and finance including public international climate finance, and to **reserve the role of carbon crediting mechanisms used towards offsetting and compliance claims for the emission sources that are well beyond the reasonable reach of host country governments** in the near- and mid-term future.

If carbon crediting project developers address the emission sources that are truly out of reasonable reach of host country governments in the near- and medium-term future, such action would be additional not only to the government's current policies and plans, but also additional to any new plans that they could potential develop in the scope of their ambition raising efforts. If it would be clarified that only these high-hanging fruit projects would be eligible for carbon crediting mechanisms used for offsetting purposes, the existence of such mechanisms should not interfere with a government's own planning process for enhancing its own emission reduction targets. There would be no perverse incentive for the government to restrict its own ambition in order to create more opportunities for carbon credit project development.

Rather, such high-hanging fruit projects could support host country governments to increase their ambition: the development and application of novel technologies on a country's territory can improve the prospects for those technologies to spill over into other areas of the economy, bringing more mitigation potential within reach in the future. Furthermore, mitigation outcomes associated with the project would accrue to the host country government after the end of the crediting period. Crediting periods would also need to be considerably shorter than those established under the carbon crediting standards developed in the Kyoto-era, and based on the regular reassessment that a certain technology is still legitimately out of reach.

Box 1

Double counting and corresponding adjustments

Corresponding adjustments on carbon credit transactions for offsetting and compliance purposes are a minimum requirement to limit double counting of the emission reduction.

A corresponding adjustment requires that the country hosting an activity is required to make adjustments to their GHG emissions inventory to account for the volume of internationally transferred mitigation outcomes. Corresponding adjustments help ensure that the same emission reduction cannot be used towards multiple purposes, such as the national climate pledge of the project host country as well as the pledges of other countries or corporates.

Under the rules for Article 6 of the Paris Agreement, agreed at COP26 in 2021 and COP27 in 2022, corresponding adjustments are required for the transaction of any authorised A6.4ERs, for any purpose. Alternatively, actors are not required to apply corresponding adjustments in the case that carbon credits are designated for a 'mitigation contribution' **(see → Section A1.3)** rather than 'authorised for the international transfer of mitigation outcomes'.

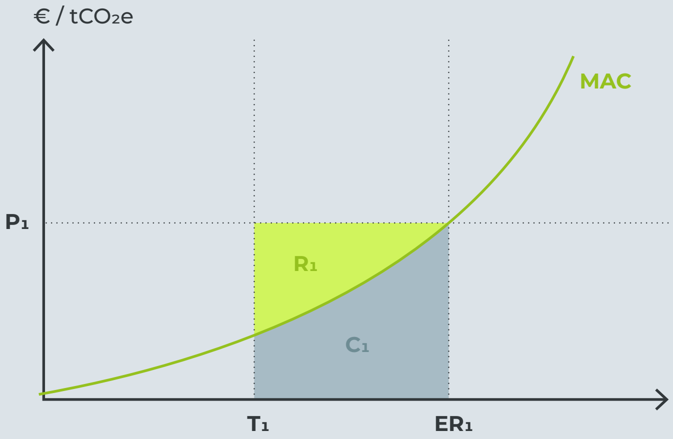
Given the potential complexities of establishing a functional system for corresponding adjustments, it remains unclear whether the carbon crediting standards and consultancies serving corporate clients will also introduce systems for corresponding adjustments, if they will align and integrate with the Article 6.4 project registry, or if they may move away from the use of carbon credits for offsetting claims altogether, as several major consultancies and carbon crediting intermediaries have announced in recent months (myclimate, 2022; ClimatePartner, 2023; SouthPole, 2023).

Note: This Box is adapted from the Corporate Climate Responsibility Monitor Methodology Version 3.0 (NewClimate Institute, 2023)

Box 2

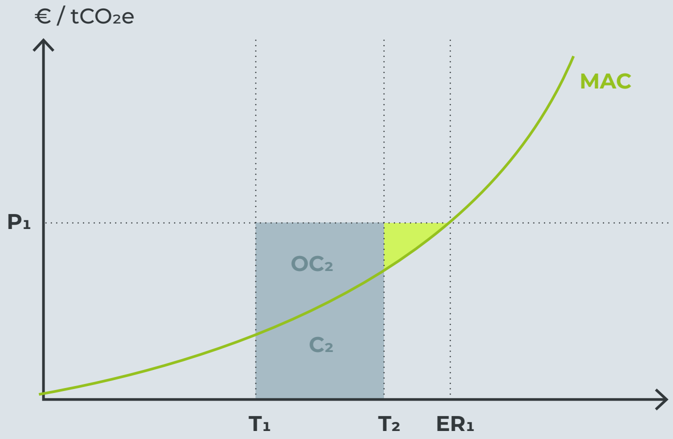
Reconciling carbon crediting mechanisms used for offsetting with the concept of gradual commitment increases

Initial national contribution target (T_1)



Percentage of emissions reductions

Potential upwards revision of national contribution target (from T_1 to T_2)



Percentage of emissions reductions

The diagrams above illustrate that countries face an economic disincentive to increasing ambition once an initial commitment level is fixed, if the sale of carbon credits authorised for offsetting or compliance purposes is an available option.

The left-hand diagram portrays the scenario where a country commits to reduce emissions up to the target T1. If, at the level T1 the marginal abatement cost (MAC) of climate mitigation measures are still lower than the demand-driven price signal for authorised carbon credits (P1), the rational course of action would be for the country to increase its emission reductions to the point at which the marginal cost of mitigation is equal to the price of carbon allowances (ER1), and to sell allowances for the emission reductions achieved between target T1 and ER1. To reach this point, the country will incur costs equal to the area C1, but will receive revenue equal to the area of the whole shaded area, and the area R1 represents a positive return. The right-hand diagram portrays the scenario where the country considers to upscale its national contribution target from T1 to T2. In the absence of market mechanisms the cost of increasing ambition in this way would be equal to the area C2. However, in the case that those measures would also be theoretically eligible for carbon crediting mechanisms for offsetting or compliance purposes purposes, the upscaling of ambition would also entail the opportunity cost equal to the area OC2, which would otherwise have been profit from the international sale of authorised carbon credits. The total cost of increasing ambition of the fixed target therefore significantly exceeds the actual cost of implementing the mitigation action. The implication of this is that a country will face economic disincentives to raise its ambition level. A further implication is that countries may actually reduce the ambition of their initial contribution in anticipation of this scenario.

Note: This Box is adapted from Carbon market mechanisms: Role in future international cooperation on climate change (Höhne et al., 2015).

1.3 CLIMATE CONTRIBUTIONS WITHOUT OFFSETTING CLAIMS

Climate contributions reflect finance provided by an organisation to support climate action beyond its own value chain, without claiming to offset, or neutralise, any actual emissions.

CLIMATE CONTRIBUTIONS THAT ARE NOT ASSOCIATED WITH OFFSETTING CLAIMS MAY BE A MORE APPROPRIATE AND CONSTRUCTIVE CHANNEL FOR VOLUNTARY BASED PROJECT FINANCE.

Climate contributions reflect finance provided by an organisation to support climate action beyond its own value chain, without claiming to offset, or neutralise, any actual emissions. They represent a financial commitment that is a complement - and in no way an alternative - to directly reducing one's own climate footprint (Fearnehough et al 2023; **see → Figure 2** for summary overview of recommendations for adopting the climate contribution approach).

For further information and guidance on the climate contribution approach, refer to our parallel publication A guide to climate contributions: taking responsibility for emissions without offsetting (Fearnehough et al., 2023)

Raising the funds

Adopt a carbon fee as the main instrument. This incentivises own emission reductions and provides a clear indication of a company's level of climate ambition.

Implement higher price levels to stimulate greater climate ambition. Responsible companies should price their emissions at a level of at least USD 100-250 per tonne and rising.

Ensure comprehensive coverage of climate footprint. Apply the same carbon fee to activities throughout the full value chain, including all emission scopes.

Spending the funds

Focus on transformative system change to deliver ambitious, sustainable outcomes.

Avoid displacing existing finance, or disincentivising government regulation, to target truly inaccessible climate action.

Figure 2
Recommendations for the climate contribution approach
(Fearnehough et al., 2023)

Climate contributions offer a more transparent and constructive alternative channel for supporting such projects. Under this construct, the mitigation outcomes of support projects are owned by the actors supported and the host country they operate in, rather than transferred to the support provider for use towards an offsetting claim. Accordingly, this can provide support for reaching and ratcheting up host countries' GHG emission reduction targets, rather than conflicting with them.

CLIMATE CONTRIBUTIONS MAY BE THE ONLY POSSIBLE MEANS OF REACHING SOME HIGH -HANGING FRUIT PROJECTS, WHEN CARBON CREDITING MECHANISMS DO NOT REPRESENT A VIABLE CHANNEL FOR SUPPORTING NEXT STEPS.

Although carbon crediting mechanisms that are used for offset claims should be restricted to high-hanging fruit projects, this is not necessarily always the most appropriate means of channelling finance to those projects. The case studies in **→ Section A3** of this report demonstrate that carbon crediting mechanisms are not a practical option for some high-hanging fruit technologies and measures that are still in earlier stages of development or entail significant risks. For example, while we identify microbiome technologies and perennial grain crops as potential high-hanging fruit projects for agriculture in Georgia **(see → Section B6)**, the required next steps for unlocking these technologies would be for further research and development in the local context, before demonstration projects can be implemented. Such projects do not lend themselves to quantifiable mitigation outcomes that can be predicted ex-ante or might not materialise in all pilot projects.

The suitability of carbon dioxide removals for carbon crediting mechanisms is also highly contentious, due to the non-permanence, scarcity and environmental costs associated with carbon dioxide removals, which means that those outcomes cannot be considered a fungible equivalent to emission reductions. Accordingly, climate contributions represent a more transparent and credible means of channelling finance to such projects.

02 IDENTIFICATION OF HIGH-HANGING FRUIT PROJECTS

2.1 SPECTRUM OF PROJECT (IN)ACCESSIBILITY

→ **Section A1** described that the high-hanging fruit of mitigation potential refers to the technologies and measures to decarbonise emission sources that remain otherwise entirely **inaccessible** to host country governments in the near- and medium-term future.

Various factors could affect the accessibility of a climate change mitigation project: for example, high upfront capital expenditures; high marginal abatement costs; low maturity or penetration of technologies and practices; high risks on potential returns; low availability of planning tools or technical analysis; and high complexity of actors involved, amongst others. For some of these indicators, their assessment against objective quantitative indicators is not pragmatically feasible.

IN THE SIMPLEST TERMS, THE ACCESSIBILITY OF A CLIMATE CHANGE MITIGATION PROJECT CAN BE CONSIDERED AS A SPECTRUM OF TECHNOLOGY READINESS AND COST. THAT SPECTRUM CONTAINS HIGH- AND LOW-HANGING FRUIT PROJECTS, EITHER SIDE OF A SIGNIFICANT GREY AREA.

→ **Figure 1** presents an illustrative representation of a spectrum of project accessibility on two axes that represent the readiness of the technology or measure and the abatement cost.

Technologies that are more expensive (right side of the diagram) and less ready for deployment (top of the diagram) are those that we consider the least accessible, in terms of these indicators. These technologies and measures represent the **high-hanging fruit**, where voluntary project finance is highly unlikely to present a conflict with host country ambition. In contrast, technologies that are cost-benefit or cost-neutral (left of the diagram) and already used as standard practice (bottom of the diagram) are those that can be considered very accessible. These technologies represent the **low hanging fruit**, where the additionality of voluntary project finance is highly contentious.

Only limited parts of this spectrum may be objectively categorised in this way. The extreme ends of technology readiness – technologies not yet demonstrated and technologies that are used as standard practice – provide a somewhat objective implication of a technology's accessibility, but the accessibility of technologies that are emerging and maturing is very context specific. The ability to objectively categorise projects as high and low hanging fruit based on abatement costs is even more limited. Marginal abatement cost estimates incorporate many underlying factors that could represent barriers on their own, such as upfront capital costs, return on investments, and risk. Affordability and risk absorption capacity depends on the capabilities of the host country and/or implementing actors. This leads to a very significant **grey area**, where the additionality of voluntary project finance is possible but cannot be certain.

CARBON CREDITING MECHANISMS FOR OFFSETTING AND COMPLIANCE CLAIMS MUST BE RESTRICTED TO THE NICHE OF PROJECTS THAT CAN BE OBJECTIVELY CATEGORISED AS HIGH-HANGING FRUITS, WHILE CLIMATE CONTRIBUTIONS MAY IN THEORY BE USED MORE FLEXIBLY.

The area of this spectrum that voluntary project finance should aim for depends on the approach for channelling finance and the claims that support providers make. → **Section A1.2** explained that high-hanging fruit projects are the only suitable option to ensure that carbon crediting mechanisms used for offsetting or compliance claims can enhance rather than undermine global climate ambition. In this case, only the end of the spectrum that allows for an objective demonstration of inaccessibility is appropriate.

For climate contributions that are not associated with offsetting or compliance claims, criteria for assessing project additionality based on considerations of accessibility are still relevant, but an objective guarantee of project 'inaccessibility' is less critical: the 'grey area' may be reasonable for climate contributions and will contain projects very worthy of support.

For projects that can be relatively objectively classified as low hanging fruits, it is much less likely that there will be a strong argument for the additionality of voluntary project finance, regardless of whether this is channelled as a climate contribution or for the purposes of an offsetting or compliance claim.

The accessibility of a climate change mitigation project can be considered as a spectrum of tech readiness and cost.

The most expensive and least mature technologies represent the **high-hanging fruit** where it is likely that projects are inaccessible without external support. The lowest cost and most mature technologies represent the **low hanging fruit** where the additionality of project support would be contentious. Many technologies and measures fall into the **grey area**, in which the accessibility of measures under may not be objectively categorised.

Technology readiness

In the regional context can serve as an objective indicator of a technology's accessibility. Technologies that are not yet demonstrated, cannot yet be considered accessible. In contrast, technologies that are already used as standard practice must be considered very accessible.

- **R&D** for new solutions
- **First-of-kind** demonstration
- **Emerging** technologies
- **Maturing** technologies
- **Standard** practice

Abatement cost

Can serve only as a subjective indicator of a technology's accessibility. Marginal abatement cost calculations incorporate many factors that could represent barriers on their own, such as upfront capital costs, return on investments, and risk. The affordability of different cost levels depends on the capability of the actor. We derive the following categories for illustrative purposes only.

- **High** (e.g. >100 USD / tCO_2e)
- **Moderate** (e.g. 50-100 USD / tCO_2e)
- **Low** (e.g. <50 USD / tCO_2e)
- **Negative / neutral**

More likely

Less likely

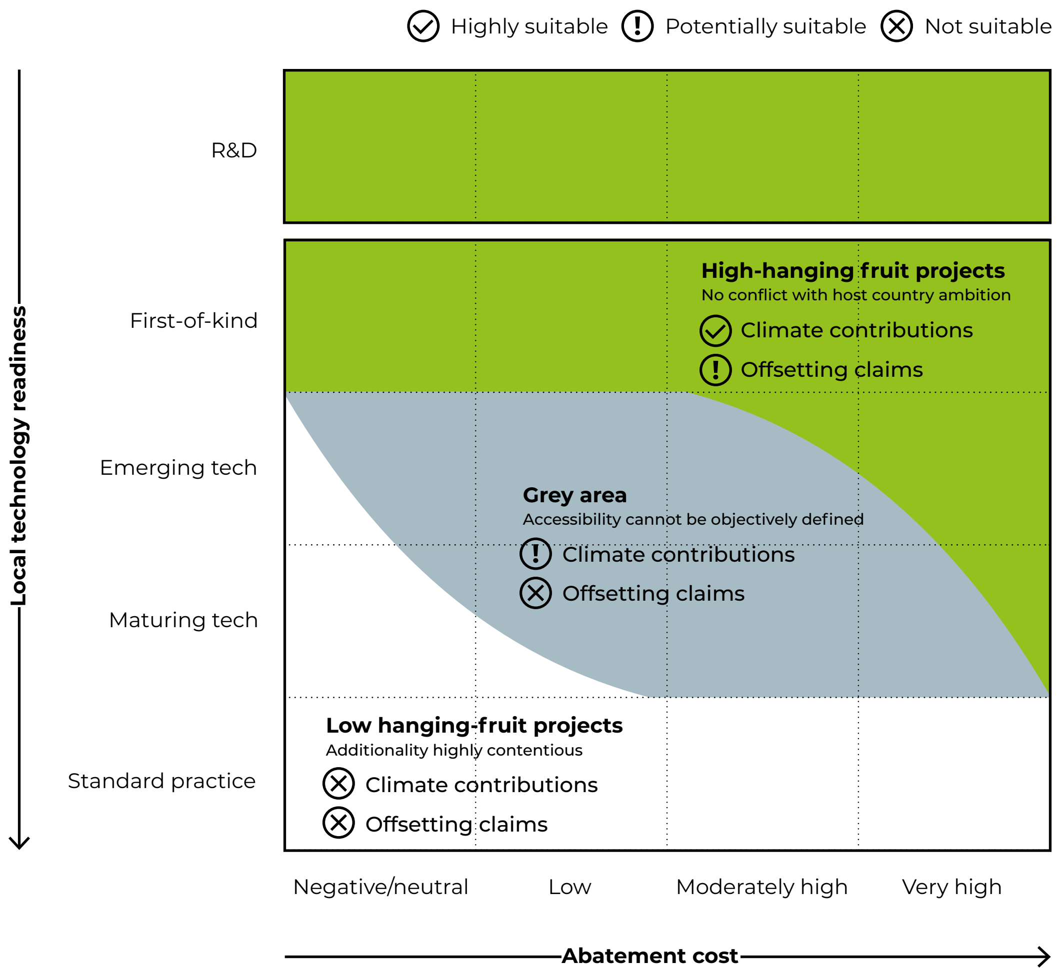


Figure 3

The spectrum of accessibility of climate change mitigation projects

2.2 DEMONSTRATION OF PROJECT INACCESSIBILITY

PROJECTS TO SUPPORT TECHNOLOGIES THAT ARE TRULY FIRST-OF-KIND OR THAT REMAIN IN RESEARCH AND DEVELOPMENT SHOULD NOT PRESENT A CONFLICT WITH HOST COUNTRY AMBITION, BUT A STRICT DEFINITION OF FIRST-OF-KIND IS NECESSARY.

Technology penetration in the regional context can serve as a pragmatic indicator of a technology's accessibility. For illustrative purposes, we distinguish between five phases of technology penetration: research and development, first-of-kind demonstrations, emerging technologies, maturing technologies and technologies that are used as standard practice.

The most pragmatic approach to confirm that a proposed project is supporting the development of new technologies that open new frontiers for mitigation is to assume that all first-of-its kind technologies are supporting, and avoiding conflict, with host country ambition.

However, the definition of first-of-kind is key to determining whether or not this truly leads to additional action. For example, the guidelines on the additionality of first-of-kind project activities under the CDM may leave considerable potential for established and accessible technologies to fall within this definition. Key parameters for the definition of first-of-kind activities include – amongst others – **the geographical area**, the **qualifying level of technology deployment** and the **timing at which first-of-kind is demonstrated**.

THE GEOGRAPHICAL AREA IN WHICH A PROJECT IMPLEMENTATION CAN BE REASONABLY CONSIDERED FIRST-OF-ITS-KIND SHOULD BE SET AT THE LEVEL OF COUNTRY GROUPINGS SUCH AS GLOBAL SUBREGIONS, RATHER THAN THE NATIONAL OR SUBNATIONAL LEVEL.

The strictest approach is to consider technologies only at the global level, but owing to regional differences – with regards to markets, climates, and capabilities, among others – there are likely to be good reasons why technologies can be reasonably considered as first-of-kind in some regions, even if they are established in others. The guidelines of the CDM identify the host country territory as the default geographical area, but also provide flexibility for project proponents to set out why it is reasonable to consider subnational regions instead. Defining a single country as the default geographical area leads to the situation that countries can be rewarded when they are laggards in technologies that are already implemented by others. Providing flexibility to stretch this to subnational regions extends this dilemma, and establishes subjectivity. The further the geographical area is granularized, the more one provides a disincentive for countries and subnational areas to delay technology deployment;

the mechanism may create a race to the bottom for technology deployment by rewarding laggards. In contrast, the higher the level of geographical area is defined, the more likely it is to turn this into a race to the top for innovation; the status of first-in-kind becomes only available for those who truly get their first. Defining the geographical area at the level of country groupings – such as subregions or neighbouring countries – would mitigate the risk of perverse incentives to delay technology uptake, while accounting for differences in circumstances and capabilities between global regions.

A DEMONSTRATION OF EXTRAORDINARILY HIGH MARGINAL ABATEMENT COSTS COULD BE AN EFFECTIVE OPTION TO IDENTIFY HIGH-HANGING FRUIT PROJECTS IF AN OBJECTIVE AND AMBITIOUS OPTION TO DEFINING THE THRESHOLD CAN BE IMPLEMENTED.

An investment analysis for the abatement activity can indicate a marginal abatement cost for the activity. This quantitative indicator could be used to assess whether the cost is beyond the reasonable reach of host country governments in the medium term. This assessment could consider nationally specific circumstances, or be based on common global eligibility thresholds:

Options for determining inaccessible marginal abatement costs based on nationally specific circumstances:

- **Indicators of economic capability:** Such an assessment could be based on indicators that reflect national economic capability and are independent of current ambition, such as GDP/capita or the Human Development Index.
- **Qualitative demonstration:** The assessment of whether the specific marginal abatement costs are well beyond the reasonable reach of host country governments in the medium-term future could be based on qualitative arguments and international expert peer review. Expert peer review – in this regard – must not include those who are linked to active private interests in the development of carbon crediting projects or markets. In any case, it would be challenging to establish objective guidelines for decisions. The development of lenient or ambiguous guidelines – which may well be in the immediate private interests of many market participants and is therefore a highly possible scenario – may lead to relatively accessible technologies being greenlighted, and consequently to the ambition raising mechanism being compromised.
- **Link to national ambition:** The assessment of whether an abatement cost is beyond the reach of host country government in the medium term should **not** be based on – or linked to – a country's current efforts, such as its targets or planned measures, since this link can penalise those countries that have been highly ambitious and engaged with climate change mitigation in the past, and can create the perverse incentive to limit efforts in the future.

For example, price floors for this criterion could be set based on scientific estimates of the global average 1.5 °C compatible carbon price signal. The full range of values identified from the literature review in the IPCC Special Report on Global Warming of 1.5 °C spans from USD 135-6,050/ tCO_2e in 2030 for compatibility with limiting warming to 1.5°C (IPCC, 2018). Targeting projects that would otherwise be inaccessible and additional to country's unilateral efforts would imply aiming at within these ranges.

Options for establishing global eligibility thresholds for determining inaccessible marginal abatement costs:

Global or regional price floors: Common global price floors could be established, below which projects could not be considered inaccessible. These price floors could distinguish between LDCs and SIDS, other developing countries and industrialised nations. Any abatement activity with a marginal abatement cost demonstrated to be below these common price floors could not qualify as inaccessible technologies. The determination of those price floors would be somewhat arbitrary, and a single price floor may affect countries differently, due to countries' different economic capabilities. If those common price floors are sufficiently high then it may also offer a pragmatic option to positively demonstrate the avoidance of conflict with the host country ambition, without extensive analysis on country-specific circumstances.

AN INTERNATIONAL "ALLOW LIST" OF EMERGING, IMMATURE AND EXPENSIVE TECHNOLOGIES COULD BE A PRAGMATIC APPROACH TO DEMONSTRATE PROJECT INACCESSIBILITY BUT DEPENDS ON STRICT DEFINITIONS.

The most pragmatic approach to demonstrating the avoidance of conflict with the host country ambition would be to check abatement activities against an internationally agreed "allow list" of emerging, immature and expensive technologies and practices, that can be reasonably assumed to be inaccessible to most host country governments in the medium-term future. Such a list could be compiled but must be updated on a regular basis to take account of new technology developments. This could be based on specific indicator thresholds such as technology readiness levels, market penetration or average abatement costs.

Those thresholds could be set differently for LDCs and SIDS, other developing countries and industrialised nations.

For example, the IEA Energy Technology Perspectives Clean Technology Guide provides a classification of Technology Readiness Levels for over 400 technologies across all energy sectors; over 200 of these technologies are classified as not yet having reached first-of-a-kind commercial application.

Technology "allow lists" that are published on an annual basis could significantly reduce the burden of proof for project developers, and would also explicitly point project developers towards emerging technologies that can benefit from increased finance flows. Prospective project developers could propose technologies for inclusion on future lists.

If such an approach for the demonstration of project inaccessibility would be implemented, great caution would be required to ensure that it is designed in a way that does not lead to the ambition safeguard being compromised. A lenient approach to defining such a list – which may well be in the immediate private interests of many market participants and is therefore a highly possible scenario – may lead to relatively accessible technologies being included, and consequently to the ambition raising mechanism being compromised. Accordingly, such lists could probably only consist of a modest collection of highly ambitious emerging technologies. Omission of specific technologies or measures from an "allow list" would not automatically indicate ineligibility, but would rather mean that a project developer would be required to demonstrate the inaccessibility of the abatement technology through another means.

It is unclear whether it would be realistic for Parties or other stakeholders to agree on an objective methodology for classifying such technologies, and there is a significant risk that the results of that exercise could reflect the lobbying power of stakeholders with interests in specific technologies.

Likewise, an international "block list" of the most mature and low-cost technologies could be established to rule out the potential consideration of the lowest hanging fruits.

Demonstrating the sufficiency of host country ambition is realistically not a practical option for ensuring that carbon crediting projects do not present a conflict with host country ambition.

In theory, demonstrating the sufficiency of host country ambition for a 1.5 °C trajectory may be a pragmatic means of demonstrating that carbon crediting projects represent no conflict with host country ambition, as long as there is explicit evidence that the proposed mitigation project is additional to, and does not adversely affect, the host countries plans to meet this 1.5 °C aligned trajectory. In practice, it is unclear whether it is realistic for Parties to agree on an objective methodology for classifying the sufficiency of Parties' NDCs.

Independent analyses such as the Climate Action Tracker (Climate Action Tracker and CAT, 2023) may be used as a basis for such assessment, but the CAT does not assess the sufficiency of targets for all countries. Furthermore, the Climate Action Tracker indicates that no major emitters have currently committed to a sufficient level of ambition for a 1.5 °C trajectory.

The methodology for carbon credit quality assessment from the Carbon Credit Quality Initiative also includes criteria that assess the host country commitment to the global temperature goal, and the stringency and coverage of the host country's NDC (CCQI criteria 7.1 and 7.2). The CCQI criteria are a strong starting point for considering host country ambition, but fall short of assessing the sufficiency of NDCs for a 1.5 °C trajectory. Rather, CCQI criterion 7.2 assesses the extent to which the host country's emission reduction target represents an advance on a current policy trajectory and therefore would require additional action from the country. Such an assessment would go some way towards addressing ambition pitfalls associated with perverse incentives for host countries to limit emission reduction targets: if the host country's emission reduction targets require significant further action beyond its current policies, then it is unlikely to approve the registration and international transfer of mitigation outcomes from low hanging fruit projects, since that would make the achievement of the country's target more difficult. However, the risk cannot be completely safeguarded unless it is demonstrated that the host country target is not only going beyond current policies but is also sufficient for a 1.5 °C trajectory.

Although demonstrating the sufficiency of host country ambition may appear a theoretically pragmatic option to ensure that carbon crediting projects do not present a conflict with host country ambition, in practice this is unlikely to be a feasible option unless a means to measure and validate sufficiency of individual targets from all countries is agreed, and in any case the option remains irrelevant until the point at which Parties have significantly improved on their emission reduction targets.

2.3 COMPATIBILITY WITH NET-ZERO EMISSION TECHNOLOGIES

See the Carbon Credit Quality Initiative for full details on the proposed methodological scoring approach for these criteria.

PROJECTS SHOULD BE COMPATIBLE WITH NET-ZERO EMISSION TECHNOLOGIES AND SYSTEMS TO AVOID LOCK-IN TO TECHNOLOGIES AND PRACTICES THAT ARE NOT ALIGNED WITH THE LONG-TERM OBJECTIVES OF THE PARIS AGREEMENT.

To support the objectives of the Paris Agreement, financial support must be channelled to the identification and scaling of long-term climate change mitigation solutions. Investments in bridging technologies that represent marginal emission reductions, but which are not compatible with zero emission technologies, may result in stranded assets, and can delay investment in those zero emission technologies.

To evaluate technologies and measures against this criterion, it is necessary to distinguish between sectors where technology options for zero emissions theoretically exist, and sectors where such technologies remain in research and development:

→ **Emission sources where technology options for zero emissions theoretically exist**

For sectors where technical options for full decarbonisation exist, whether they are commercially established or emerging, the supported technologies and measures must be compatible with a zero-emission sector. Emission reduction projects would not meet this criterion if they involved the continued use or optimisation of technologies that would rather need to be phased out to reach zero emissions. For example, technologies that increase the efficiency or otherwise marginally reduce the emissions of fossil fuel combustion would not qualify, unless they are also compatible with renewable energy technologies.

→ **Emission sources where technology options for zero emissions remain in R&D**

For these harder-to-abate sectors, the supported technologies should be compatible with other best available or emerging decarbonisation technologies within those sectors.

2.4 EXAMPLES OF HIGH-HANGING FRUIT PROJECTS

The case studies in section B of this report assess the landscape of mitigation potential for building heat in Mongolia, transport in Indonesia and agriculture in Georgia to identify potential high-hanging fruit technologies and measures, for illustrative purposes. This section summarises the results of those case studies.

BUILDING HEAT IN MONGOLIA

Ulaanbaatar is heavily reliant on coal for heating buildings and informal settlements in an extremely cold environment. The adoption of energy efficiency measures and a shift to renewable energy-based heating technologies could significantly reduce emissions, but this transformation poses significant economic, infrastructural, and technical challenges.

High-hanging fruit projects can demonstrate the feasibility of available solutions for zero-emission heat in severely cold temperatures. The decarbonisation of the Ulaanbaatar heating sector will require a mix of novel high-hanging fruit technologies for district heating and building-scale renewable energy.

→ **Section B4** identifies the following measures as high-hanging fruit projects in the Mongolian context.

→ **Solar assisted air-source or ground-source heat pumps (building-scale)** can provide reliable and efficient year-round heating since new technological developments have overcome traditional barriers. New two-stage compression air-source heat pumps (ASHP) can provide heat in ambient temperatures down to -40 °C. They can be combined with solar collectors to overcome potential barriers related to frost formation and to increase efficiency by around 40%. Solar collectors can also be combined with ground-source heat pumps to overcome the barrier of thermal soil imbalance by injecting thermal energy into the ground, and increasing the system efficiency.

Commercially available two-stage air-source heat pumps have been successfully demonstrated for a small number of non-insulated buildings in pilot projects in Ulaanbaatar, but high upfront investment costs and low awareness means that this remains a novel measure. Ground source heat pumps have been applied only sparingly to public buildings in Ulaanbaatar, but pilot projects and simulations for solar assisted ground source heat pumps in Northern China have demonstrated excellent performance in extremely cold temperatures.

The installation of building-scale heat pumps may be highly suitable for voluntary project-based finance. Project-level boundaries for interventions can be easily established in the form of individual buildings, clusters of buildings, or districts, depending on the volume of finance available for the project.

→ **Retrofit of district heating networks for low temperature supply** is necessary to integrate renewable energy technologies into the system, but low temperature networks remain in limited use worldwide. The lifecycle costs and marginal abatement cost of this investment remain highly uncertain, depending on the costs and performance of associated large-scale heat supply technologies, which are not yet tested in the Mongolian context.

The large-scale investments required for upgrading district heating, and the system-wide approach to planning such infrastructure, represent significant challenges for project-based voluntary climate finance; for much of the network, it could be challenging to establish practical boundaries for project interventions. However, there is potential for projects to demonstrate and begin the deployment of technologies that would need to be scaled up and replicated through larger infrastructure projects.

→ **District scale heat pumps and solar thermal systems** can be a highly efficient solution, but such large-scale systems are yet to be tested in the Mongolian context, despite optimistic indications of technical feasibility.

We identify these measures as high-hanging fruit projects on account of their low penetration in the Mongolian market and their high cost. These projects would currently be very unlikely to be implemented without external support, even under measures to increase climate change mitigation ambition, since the costs and/or novelty of the technologies means that they are likely beyond reach of unilateral host country ambition raising. This could change in the medium-term, if the increased deployment of these technologies leads to them becoming more accessible. These measures are explored in further detail in → **Section B4**.

The challenges faced in the Ulaanbaatar heating sector are similar to in other parts of the country, as well as in other countries located in cold climates. These high-hanging fruit projects could also be relevant in other cities with existing district heating networks or the ability to develop such a network. This could include many cities in urban Northern China, where district heating systems already serve a majority of urban heating demand (IEA, 2017). District heating systems face similar challenges in cities throughout Kazakhstan (IEA, 2020), as well as some cities in Kyrgyzstan (World Bank, 2015) and Uzbekistan (TTC and TTE, 2018). There may also be potential for the redevelopment of the dismantled district heating networks in some areas of Georgia (Energy Community, 2022).

TRANSPORT IN INDONESIA

Energy consumptions and emissions from Indonesia's transport sector have sharply increased due to rapid economic growth, urbanisation, and private vehicle ownership. Urban public transport, electrified vehicle fleets, and expanded rail infrastructure could significantly reduce emissions if powered with renewable energy.

Such measures require centrally planned infrastructure developments for modal shift and electrification, but high-hanging fruit demonstration projects can play an important role to kick-start the uptake of technologies.

→ **Section B5** identifies the following measures as high-hanging fruit projects in the Indonesian context.

- → **Electrification of inner-city or inter-city passenger transport buses** can decarbonise the passenger transport sector on inner-city routes, and potentially short distance inter-city routes. The emission reduction potential depends on the parallel expansion and decarbonisation of the electricity grid. Electric buses have been demonstrated to be a feasible technology for inner-city transport in the Indonesian context, although costs remain high, and they remain in the early stages of adoption. To accelerate the transition, additional funding could be channelled to projects aiming to trial electric buses in Indonesian cities.
- → **Electrification of small and medium-sized passenger and freight watercraft** can be a particularly relevant technology to demonstrate in the Indonesian context, given that Indonesia is an archipelago nation with over 6,000 inhabited islands and a significant amount of passenger and freight transported by water. With hundreds of formal ferry connections,

many of which span only short distances, opportunities may exist for demonstration projects of various scales. Community-scale projects for electrified small vessels combined with mini-grid systems could also be demonstrated with significant potential for upscaling, given that more than 700,000 vessels transport goods and people in small communities, many of which are off-grid.

→ **Electrification of medium and heavy-duty freight trucks** could significantly reduce the emissions from fuel combustion in the Indonesian freight transport sector, which is mostly road based and dependent on old, emission-intensive trucks. As for other electrification technologies, the emission reduction potential depends on the parallel expansion and decarbonisation of the electricity grid and charging infrastructure. A truck replacement programme in Indonesia entails significant challenges for project-based finance: such a programme would likely depend on a centralised plan for the installation of charging infrastructure, and a mechanism to channel financial support to a highly fragmented market of over one million truck operators operating very small fleets. A steppingstone which could be accessible to project-scale finance, would be the installation of demonstration projects for commodities transported on short distance routes and fixed corridors, where charging infrastructure would only be required at the origin and destination. This could include for example, short-distance freight corridors between major factories or industrial parks and nearby ports.

These are identified as high-hanging fruit technologies in the Indonesian context on account of their high costs and low market penetration: electrified buses are emerging in Indonesia, but electrified watercraft or freight vehicles are not yet in use in the country.

The electrification of heavy transport in Indonesia is not necessarily conducive for project-scale finance; it will require centrally planned infrastructure for the expansion and upgrade of the electricity grid, expansion or renewable electricity generation capacity, and charging infrastructure, among other infrastructural challenges. However, project finance can play a role to accelerate the onset of this transition through demonstration projects in closed boundary environments that do not depend on national infrastructure developments, such as transport routes confined to a fixed corridor between two fixed points. Demonstration projects could span a range of scales, from off-grid community-level projects combined with mini-grids, to the introduction of medium-sized inter-island e-ferries combined with charging infrastructure in ports.

These measures are explored in further detail in → **Section B5**.

Demonstration projects for the electrification of heavy-duty transport would also currently be likely to represent high-hanging fruit projects in other countries. Such technologies should become more accessible in the medium-term, as their lifetime costs move towards parity with new ICE technologies, as some analysts forecast within the next 5 years. However, these technologies may remain prohibitively expensive in countries where a large proportion of the vehicle stock derives from imported used vehicles.

Infrastructure and services for non-motorised transport, expansion of rail and public transport systems, and the electrification of light duty vehicles are immediate priorities for the decarbonisation of the transport system in Indonesia. We do not identify these measures as potential high-hanging fruit projects, but rather we consider that such developments could be supported through government spending and multilateral concessional finance, given the very large upfront capital expenditures combined with the relatively accessible marginal abatement costs of these measures.

AGRICULTURE IN GEORGIA

Georgia is in the process of modernising and commercialising the agriculture sector to increase productivity and profitability. Much of the sector is still characterised by small-scale and labour intensive farming operations. Emissions from the agriculture sector account for a fifth of Georgia's total national GHG emissions and are projected to increase by approximately 40% between 2015 and 2030, mostly due to increased emissions from agricultural soils.

High-hanging fruit projects can support the emergence of new technologies and measures for deep emission reductions in croplands, but not all of these measures will be suitable for carbon crediting mechanisms.

→ **Section B6** identifies the following measures as high-hanging fruit projects in the Georgian context.

→ **Electrified farm machinery and equipment**, including battery-powered tractors, harvesters and dryers, can reduce the direct emissions associated with energy use in agriculture, provided it is coupled with renewable power generation. Electrified farm machinery technologies are not yet available in Georgia. The electrification of large-scale farm machinery and equipment is not yet widespread in any country, but there are prospects for these technologies to become competitive in the mid- to longer-term future. When a market for zero-emission farming machinery becomes accessible for Georgia, finance for demonstration projects may be necessary to overcome high upfront capital costs.

- → **Soil and plant microbiome technologies** can enhance carbon sequestration and reduce nitrous oxide emissions. Microbiome cocktails for cropland inoculation have reached the global market, but remain at an early stage of development and are oriented more at the major global cash crop markets; they are not yet used in Georgia. More advanced methods of in-situ cropland microbiome modification have only recently come onto the biochemical engineering research agenda at the global level.
- → **New perennial grain crops** can enhance carbon sequestration and decrease soil erosion, but research and development is needed to adapt these crops to the Georgian context. New perennial grains are gaining traction at the international level as a high potential climate change mitigation measure, but are not in widespread use in any country. International research efforts are likely to significantly increase the availability of perennial cropping over the next decade.

We identify these measures as high-hanging fruit projects on account of their current inaccessibility in the Georgian context; none of these solutions are currently available on the Georgian market.

For microbiome technologies and new perennial grain crops, the mitigation potential of these measures may be very significant, but this remains uncertain due to the early stage of research and development and uncertainty regarding how global solutions will fare in the Georgian context. For some of these more innovative measures in cropping systems, Georgia could benefit from participating in global research programmes, in order to support an increased understanding on the local suitability of solutions that emerge, and to lead more quickly to the development of more locally appropriate options.

Project-based finance delivered through a climate contribution model that is not attached to carbon crediting mechanisms could be an effective means of supporting the next steps for Georgian participation in R&D programmes, locally-specific R&D, and pilot projects to test emerging locally-specific solutions.

But the suitability of these measures for project-based finance through carbon crediting may be more limited. More research and development is likely necessary on the local level before projects can be implemented, making these measures currently somewhat unsuitable for carbon crediting mechanisms that depend on quantifiable emission reduction outcomes. The non-permanence of carbon dioxide removal outcomes also makes some of these projects unsuitable for offsetting or compliance claims, even once those outcomes can be quantified **(see → Section A1.2)**.

These measures are explored in further detail in → **Section B6**.

Whether or not such measures could constitute high-hanging fruit projects outside of the Georgian context will be highly variable between countries. In some industrialised countries, zero-emission machinery is already emerging while in most developing countries and emerging economies these technologies are still very novel. The accessibility of microbiome technologies and perennial grain cropping will depend on the extent of existing research and development in the specific region since the development of solutions is very specific to local soils and crops. Some of these measures are emerging in countries where the locally-specific R&D efforts are well developed, while in other countries the state of knowledge and availability of these measures is still far more limited.

03 OUTLOOK FOR SHIFTING FINANCE TO THE HIGH HANGING FRUIT

IT IS HIGHLY CHALLENGING TO IDENTIFY HIGH-HANGING FRUIT PROJECTS TODAY. A PIPELINE OF PROJECTS IS NOT READILY AVAILABLE AND WILL REQUIRE INTERVENTIONS TO DEVELOP. IF ADDITIONALITY IS TAKEN SERIOUSLY, EXPECTATIONS OF A FUTURE MASS MARKET FOR CARBON CREDIT TRANSACTIONS SHOULD BE TEMPERED.

Since emission reduction projects registered under crediting programmes to date have been mostly developed in the context of cost-saving, rather than ambition-raising mechanisms, we understand that there are very few, if any, examples of existing credited projects that represent those high-hanging fruits, and which could be considered truly in line with safeguarding and raising ambition in the context of the Paris Agreement.

Project developers that look to operate in post-2020 carbon crediting mechanisms with high-hanging fruit mitigation projects will need to adjust their market search to move from upscaling more accessible mitigation technologies, to the development and implementation of more innovative technologies for harder-to-abate emission sources. This will take considerable time and resources to develop.

The search for high-hanging fruits does not align well with natural market forces, since markets typically serve to deliver a product or outcome at the lowest possible cost, within the given parameters. Accordingly, targeted interventions will be required to foster this development.

Moreover, the scope of technologies and measures that would count as high-hanging fruits will be a gradually decreasing niche of activities, as countries' ambition and capabilities increase over the years. On this consideration, it seems unlikely that high-hanging fruit mitigation projects can serve the mass demand for carbon credits underpinning offsetting claims or compliance markets that some analysts have forecast for the coming decades. Rather, if there are any prospects for such mechanisms and associated claims to be substantiated in a credible way that safeguards against ambition pitfalls, those claims can only play an ever increasingly niche role in the climate change mitigation strategies of nations, subnational governments, companies and individuals.

Based on a consideration of these limitations, we propose the following recommendations for targeted interventions to support the development of a pipeline for high-hanging fruit projects, and to channel voluntary climate finance with more transparency and integrity:

→ **Redefining additionality:** A redefinition of additionality and/or a labelling mechanism is necessary to ensure that market mechanisms can play a role to identify solutions. Since market mechanisms will always search for the most cost-effective option within given parameters, it is only feasible for market mechanisms to play a role in financing the high-hanging fruit of climate change mitigation potential if those given parameters are adjusted, such that the definition of project "additionality" includes a demonstration of project inaccessibility **(→ Section A2.2)**. Since this is the only option for credible offsetting and compliance claims **(see → Section A1.2)**, such a redefinition should be highest priority if market mechanisms and offsetting claims are to play any role in the climate strategies of countries or non-state actors from this point on.

→ **Introducing labels for high-hanging fruit projects:** Given the currently very limited pipeline of high-hanging fruit projects that could be implemented in the immediate future, some carbon crediting standards and registries may be reluctant to immediately adopt a sufficient definition of additionality. A labelling mechanism for high-hanging fruit projects to clearly demonstrate the difference between "possible" and "guaranteed" additionality should be a minimum for ambitious standards and registries. Such a label could also carry implications with regards to the use of the carbon credits; for example, carbon credits should only be authorised for offsetting and compliance claims if they can guarantee additionality.

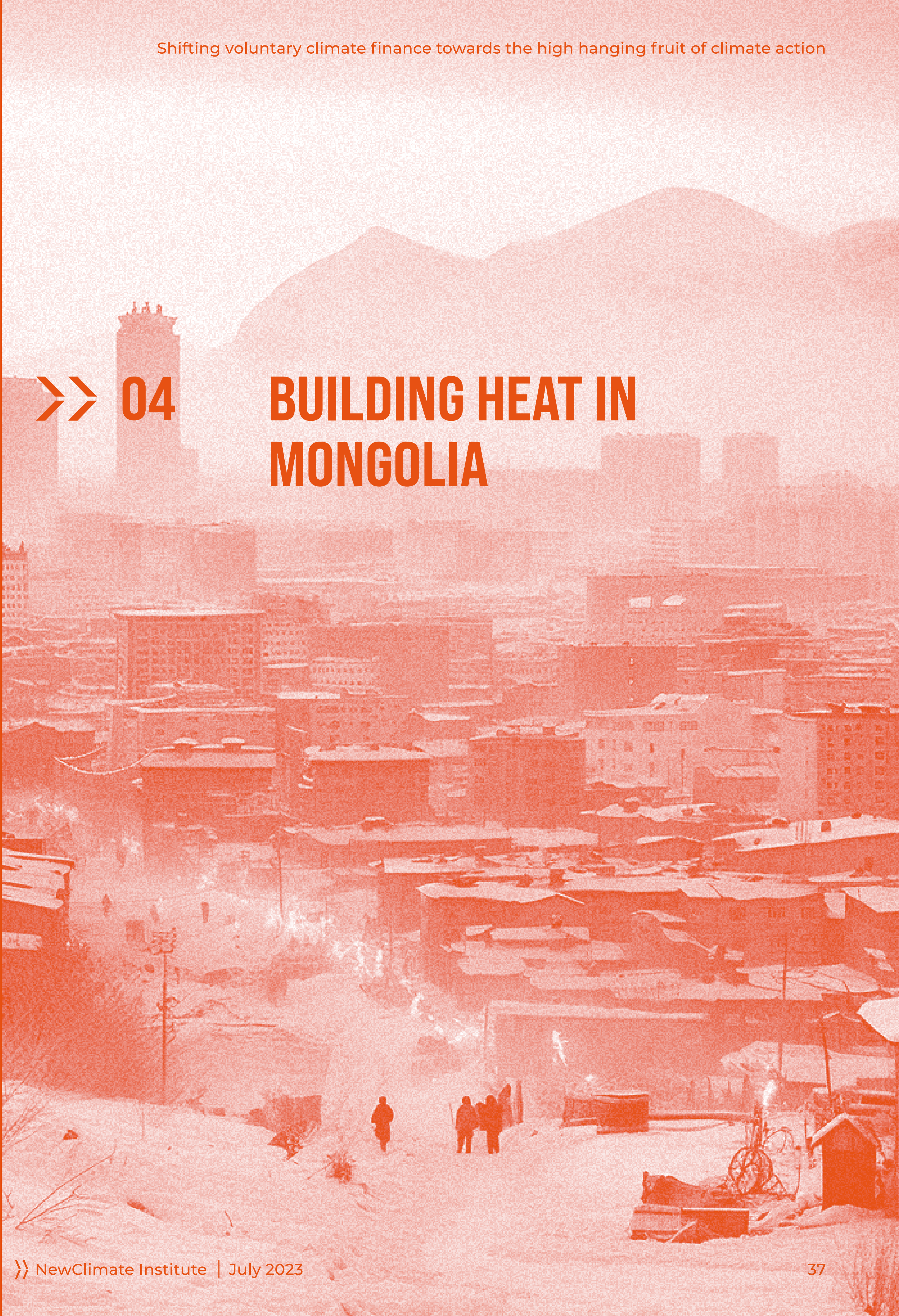
→ **Establishing funds for channelling climate contributions:** There is an important role for either new or established initiatives to channel climate contributions towards projects that have not been reached by existing market mechanisms, such as less mature technologies or projects with less readily quantifiable outcomes. For example, Milkywire's Climate Transformation Fund and TimeCO_2's Planet Portfolio are initiatives that collect contributions to finance more pioneering climate solutions for decarbonisation, carbon removal and restoring and protecting nature. Such initiatives should be scaled up and replicated.

→ **Accelerating the transition to climate contributions:** The climate contribution approach should by its nature release a race to the top where high-hanging fruit projects become more interesting to support providers, if the amount of an actor's contributions is a fixed amount based on a fee per tonne of emissions.

→ **Corporate leadership:** Given the limited readiness of the market to present a compelling project pipeline in the present, companies that are interested to support high-hanging fruit projects to demonstrate their climate leadership will need to play a driving role. This could come in the form of directly identifying ambitious projects to support, contributing to initiatives and/or funds that aim to develop and finance a pipeline of high-hanging fruit projects, or applying pressure to existing partners and intermediaries to take a proactive approach in this transition. By doing so, companies will not only support their own climate strategies but can make an even more significant contribution to the evolution of voluntary climate finance.

→ **Proactive intermediaries:** Established consultants and intermediaries that are already working with companies on their climate strategies and the channelling of their voluntary climate finance are in a pivotal position to accelerate the evolution of voluntary climate finance flows to high-hanging fruit projects. In some regards, the sustainability of their own business models also depends on this. These consultants and intermediaries should play a proactive role in looking for and generating project ideas for high-hanging fruit projects, as well as raising awareness amongst their corporate clients on the relevance – or necessity – for supporting such projects. Consultants and intermediaries that opt for the conservative approach of passively waiting for supply and demand for high-hanging fruit projects will not only slow down the transition, but will also find themselves far behind once that supply and demand has been established by more ambitious competitors that look to offer the most credible services based on the present context and the latest scientific evidence.

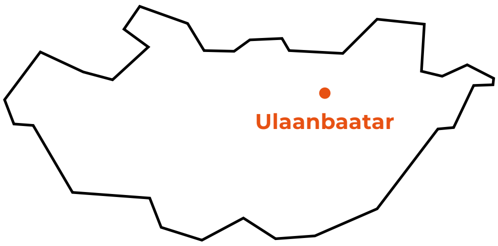
ILLUSTRATIVE CASE STUDIES FOR PROJECT IDENTIFICATION

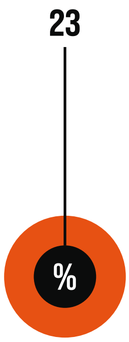


04 BUILDING HEAT IN MONGOLIA

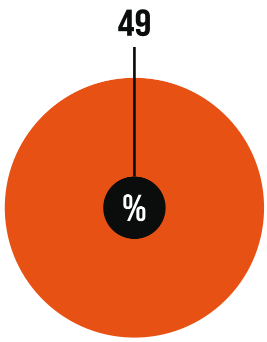
The heating sector in Ulaanbaatar (Mongolia) faces significant challenges to decarbonise due to the severely cold climate and the dependence on existing infrastructure for combined heating and power from coal.

Urban migration is leading to rapid growth for heat demand, which is already a major source of GHG emissions and air pollution.





Proportion of national GHG emissions accounting to the heating sector in Ulaanbaatar 2015.



Proportion of the Mongolian population living in Ulaanbaatar in 2020, up from 26% in 1986.

High-hanging fruit projects can demonstrate the feasibility of available solutions than can provide zero-emission heat in severely cold temperatures.

Solar assisted air-source or ground-source heat pumps (building-scale) can provide reliable and efficient year-round heating since new technological developments have overcome traditional barriers, but upfront capital expenditures are high and there is limited experience with the technologies in Mongolia.

Retrofit of district heating networks for low temperature supply is necessary to integrate renewable energy technologies into the system, but low temperature networks remain in limited use worldwide.

District scale heat pumps and solar thermal systems can be a highly efficient solution, but such large-scale systems are yet to be tested in the Mongolian context.

4.1 EMISSION DRIVERS AND DECARBONISATION CHALLENGES

ULAANBAATAR IS HEAVILY RELIANT ON COAL FOR HEATING BUILDINGS AND INFORMAL SETTLEMENTS IN AN EXTREMELY COLD ENVIRONMENT. THE ADOPTION OF ENERGY EFFICIENCY MEASURES AND A SHIFT TO RENEWABLE ENERGY-BASED HEATING TECHNOLOGIES COULD SIGNIFICANTLY REDUCE EMISSIONS, BUT THIS TRANSFORMATION POSES SIGNIFICANT ECONOMIC, INFRASTRUCTURAL, AND TECHNICAL CHALLENGES.

Mongolia is one of the coldest countries in the world with a long heating season of about 8 months. In winter, temperatures drop to as low as -40°C, resulting in a highly energy intensive heating sector which is, due to rich domestic coal resources, largely generated from coal (Azhgaliyeva et al., 2021). In 2015, the Mongolian building sector was responsible for about 23%[1] of national GHG emissions.

Following the end of socialism in 1990 and the introduction of market-based liberal economics, the Mongolian economy has gradually shifted from agriculture-centred to industry- and mining-centred, driving a high flow of rural and nomadic people into urban centres (Hamiduddin et al., 2021). The share of the Mongolian population living in Ulaanbaatar, the capital, has increased rapidly: from 26% in 1986 to 49% in 2020 (Stryi-Hipp et al., 2018; The World Bank, 2021; World Population Review, 2021). The vast majority of that population growth settle in informal housing districts, so called ger districts, with no or poor access to centralised heating systems and electricity. This leaves informal households reliant on inefficient raw coal burning to meet heat demand in the winters, causing high levels of GHG emissions and air pollution.

In formal housing districts of Ulaanbaatar, heat is distributed via the district heating network, supplied by coal-based CHP plants and coal boilers which are approaching or already beyond its expected lifetime. Meanwhile, the increasing population increases the demand for centralised heating which can no longer satisfy the demand. Thus, the heating capacity is not only in need for upgrading, but also needs to be expanded. Investing in new CHP plants could lock-in coal into the heating system for decades to come, but the abundant coal resources of the country risk hindering the transition to renewable energy based heating systems. With coal deposits representing 10% of global coal reserves, and production largely driven by international demand, there is little political will to promote renewable based solutions at the expense of existing coal capacities (Carlisle and Pevzner, 2019).

1 Author's calculations based on (Stryi-Hipp et al., 2018; The World Bank, 2021; World Population Review, 2021).

In order to change the current trajectory of expanded coal-based heat capacities to meet a rapidly growing heat demand, Ulaanbaatar is in high need of support, not only for a technology transition, but importantly also for urban development to enable an equitable transition and access to clean, affordable and reliable heat for all its citizens. The surroundings of the city do not only have plentiful coal resources but also substantial renewable energy potential which remains largely unexploited. The adoption of energy efficiency measures and a shift to renewable energy-based heating technologies could significantly reduce emissions from the heat sector, bringing it to zero emissions in the long term. Such transformation, however, poses various economic, infrastructural, and technical challenges. The city stands at a crossroads providing an opportunity to initiate the gradual shift to a clean heating system and avoiding coal lock-in but lacks the means to do so without external support.

Achieving a low carbon heating system will require two main shifts, namely increased energy efficiency at the demand and supply sides, and the decarbonisation of the heat supply through the wide deployment of electricity and renewables-based heating. These two shifts are further described in the next two sections.

THE ENERGY EFFICIENCY OF THE BUILDING STOCK IN ULAANBAATAR REMAINS RELATIVELY POOR. INFORMAL COLLAPSIBLE DWELLINGS – IN WHICH 30-60% OF THE POPULATION LIVE – ARE HIGHLY INEFFICIENT WITH LIMITED POTENTIAL FOR INSULATION MEASURES. THE DISTRIBUTION LOSSES OF AGED DISTRICT HEATING SYSTEMS ARE HIGH, AND THOSE DISTRICT HEATING NETWORKS DO NOT SERVE THE INFORMAL DWELLINGS.

The Mongolian heat supply can be grouped into two main categories: centralised (district heating) and decentralised (no access to district heating). Ulaanbaatar and various other cities and villages have existing district heating systems which distribute heat generated from coal-based CHP or heat-only boilers (HOBs). A large proportion of informal housing (gers), however, are not connected to a district heating system and depend on decentralised solutions which are mainly coal stoves and which operate at a very low efficiency (about 35 45%) (Savickas, 2020).

Although district heating is a highly energy efficient option for heat transmission and distribution in densely populated areas, the existing district heating systems in Mongolia are old and of poor quality with high losses. The oldest parts of the system were commissioned in 1959, and only an estimated 50% of the current system is considered to be in fair condition (Yun Wu et al., no date). The distribution losses in the Ulaanbaatar district heating system are high at about 17%, compared to 9% and 7% in Harbin and Stockholm, respectively (Yun Wu et al., no date). The upgrading and expansion of existing district heating systems in Mongolia could thus contribute to significant energy and GHG emission savings.

However, energy savings is not the only aspect of such measures. Perhaps more importantly, modern low-temperature district heating systems is a precondition to widely integrating various renewable energy technologies into the energy supply of a district heating system (Nielsen, 2022). The upgrading and rehabilitation of existing networks will therefore be a vital first step in decarbonising the Mongolian centralised heating sector.

Similarly, substantial energy savings could be achieved on the demand side. Although the severe cold climate in the city will always generate a high energy demand during the heating season, significant energy savings could be made through improving the building envelope of existing buildings. The majority of the housing stock in Ulaanbaatar is made up of inefficient and poorly insulated pre-cast concrete panel buildings from the 1970s to early 90s, housing more than 20% of the city's population (GIZ, 2017).

In addition to energy savings, improved energy efficiency of buildings could also generate technology investment cost savings as lower energy demand would contribute to lower peak heat demand. Less installed renewable energy-based heating capacity would thus be required, lowering the necessary initial investment costs for the installation of those capacities. As such, energy efficiency measures could not only save energy costs and GHG emissions but could also facilitate a smoother integration of renewable energy-based heating technologies to the heat supply.

The share of the city population living in gers is large and growing (about 30-60%[2]) (Stryi-Hipp et al., 2018; Carlisle and Pevzner, 2019; Rosato et al., 2019). Traditional ger tents (collapsible dwellings traditionally used by pastoralists) are the most common dwelling type (Hamiduddin et al., 2021). Ger tents are highly inefficient with limited insulation potential, leading to heating demands per square meter significantly higher than buildings in the formal housing districts. They are also not connected to central water or sewage (Plueckhahn, 2021). The inefficient coal stoves used to generate heat in ger tents result in high expenditures on fuels, normally accounting for 25 40% of household incomes (Carlisle and Pevzner, 2019).The Mongolian government has tried to address this issue through the replacement of gers with newly constructed apartment buildings connected to district heating in the Ger Area Development Programme under the Master Plan 2020 (Plueckhahn, 2021). The project, however, has been challenged by the lack of clear measures and changing parties in the administrative power (Matsumiya, 2019).

2 The estimated share of the city's population residing in gers varies across studies. The quantifications in this study are based on data presented in (Stryi-Hipp et al., 2018) where 30% of the Ulaanbaatar population is assumed to reside in gers.

ULAANBAATAR'S HEAT SUPPLY SYSTEM IS HIGHLY DEPENDENT ON OLD COAL-FIRED PLANTS WHICH ARE AT THE LIMIT OF THEIR CAPACITIES AMID RISING ENERGY DEMAND. THE CONDITIONS EXIST TO DIVERSIFY THE HEAT SUPPLY MIX WITH THE INTEGRATION OF RENEWABLES, BUT THIS REQUIRES SIGNIFICANT INVESTMENTS IN LARGE SCALE HEAT PUMPS AND THE REFURBISHMENT OF THE DISTRICT HEATING SYSTEM.

The Ulaanbaatar district heating network is supplied by three coal-based CHP plants and one HOB out of which two continue to operate beyond their usual retirement age. This leaves a highly fragile heat supply system which could lead to catastrophic consequences in case of failure in wintertime (Carlisle and Pevzner, 2019). The rising heat demand leaves the district heating system struggling to supply heating to all new buildings (GIZ, 2017). This supply gap provides an opportunity to initiate the transformation of the heat supply to low-carbon technologies while avoiding locking-in technologies reliant on fossil fuels (Carlisle and Pevzner, 2019). The district heating network provides the opportunity to build on existing infrastructure, even if it is in need of refurbishment. As several heating technologies can supply the network, low-carbon heating technologies can gradually be integrated, initiating the diversification of the heat supply mix.

In terms of low-carbon heating technologies, previous studies have shown that, in the context of Ulaanbaatar, the electricity- and renewables based heating technologies carries the largest mitigation potential on a system-wide scale, with smaller contribution potential from industrial excess heat and waste incineration (Stryi-Hipp et al., 2018; Nilsson et al., 2022). Because of the significantly higher energy efficiency of heat pumps compared to resistive heating (about 100% for resistive heating compared to about 350% for a ground-source heat pump), heat pumps can deliver the same amount of heat using substantially less electricity compared to other electric heating technologies such as resistive heaters. A lower electricity consumption reduces the amount of renewable electricity deployment required, but also contributes to lower operational costs as less money need to be spent on electricity. Large-scale heat pumps can be integrated to district heating networks and are already operating successfully in various locations such as in Denmark (Nielsen, 2022).

The energy efficiency, stability of the system, and electricity consumption can be further improved by combining heat pumps with the direct use of renewable heat (e.g. solar thermal) in hybrid systems. Even though solar radiation is generally high in Mongolia, a heating system based on solar thermal exclusively might struggle to satisfy the full heat demand at all times, particularly in very cold periods (Rosato et al., 2019). However, by maximising the use of solar thermal in a hybrid system, the operation and efficiency of heat pumps can be improved while free and clean solar thermal heat is maximised. The robustness of the system can be further improved through injecting excess solar thermal heat to the ground (or using other modes of storage).

A study in Harbin in northern China (with similar climatic conditions as Ulaanbaatar) tested a solar assisted ground source heat pump (SAGSHP) on a detached house. The results suggested that about 50% of the annual heat demand could be met by solar thermal energy (Wang et al., 2010). Another study simulated the operation of a large-scale SAGSHP for 30 buildings in Ulaanbaatar, which distributed heat via a district heating network. Solar thermal energy was injected into the ground to maintain the temperature of the ground and improve the efficiency of the heat pump. The simulation proved successful and could satisfy the full heat demand all year round (Shah et al., 2020).

The gradual integration of such systems to the Ulaanbaatar district heating network could, over time, replace significant shares of the current CHP heat supply. This could take place simultaneously as the district heating network is further expanded to connect new buildings, and ger households are transitioning to formal settlings. But such measures face significant challenges. The cold winter temperatures decrease the efficiency of air-source heat pumps, for instance, as well as increasing the risk for other technical complications. The deployment of ground-source heat pumps is technically feasible, but due to the cold climate, the required depth of the boreholes increases which is costlier. The long winter season further challenges the deployment of various technologies due to the frozen ground; extending the district heating network, for instance, is more feasible to do during warmer months.

However, since ger areas are not connected to the district heating network, their heating supply can only be decarbonised through the introduction of additional measures. Given existing plans for the gradual migration from gers to standard dwellings, there are limited economic incentives to install capital-intensive heating technologies on impermanent ger dwellings. But the currently used coal boilers used for heating in the majority of those cause to significant GHG emissions and air pollution. Mitigation options for those must therefore be evaluated. Considering the relatively high capital cost of cleaner and more energy efficient options such as heat pumps and solar thermal, those are not suitable options. Instead, electric resistive heaters, which are less capital-intensive and easier to install, could by suitable near- to mid-term solutions to reduce emissions in ger areas.

Achieving emission reductions through the deployment of electric resistive heaters, however, requires a reliable and clean electricity supply. The electrification of heat must therefore be coupled with the expansion of renewable electricity capacity, as well as grid infrastructure.

4.2 IDENTIFICATION OF HIGH-HANGING FRUIT PROJECTS

This section provides an overview of the various potential climate change mitigation measures for heating buildings in Ulaanbaatar, to identify potential high-hanging fruit projects and options for supporting measures that are potentially more accessible.

→ **Table 1** presents a summary of the extent to which a range of measures fulfil the criteria to be considered high-hanging fruit projects. We have looked at a non-exhaustive selection of measures for energy efficiency, building-scale heat supply technologies, and district-scale heat supply technologies. Other potential technologies – including water-source pumps, geothermal heating and synthetic fuels – are not included in this comparison as they were determined by Nilsson et al (2022) to be currently unsuitable for the local context in Ulaanbaatar.

District-scale biomass and waste is marked as a potentially inefficient solution towards the objective of net-zero emissions in the Ulaanbaatar context; given the limited supply potential supply of biomass and waste, its use may be limited to co-firing coal CHP plants, which could further incentivise the use of coal CHP plants and delay their phase-out (Nilsson et al., 2022). Green hydrogen could deliver zero emissions heat but is unlikely suitable in the Ulaanbaatar context due to its inefficiency compared to other potential technologies and the resource-intensive nature of its production (Nilsson et al., 2022).

The assessment of individual measures presented in → **Table 1** and in the following pages represents the authors' judgement based on interviews with national experts and literature review.

THE DECARBONISATION OF THE ULAANBAATAR HEATING SECTOR WILL REQUIRE A MIX OF NOVEL HIGH-HANGING FRUIT TECHNOLOGIES FOR DISTRICT HEATING AND BUILDING-SCALE RENEWABLE ENERGY.

→ **Table 1** identifies the following measures as high-hanging fruit projects in the Mongolian context.

- Upgrading the district heating network for low temperatures

	Marginal abatement cost				Maturity and availability				Suitability of project-finance				Net-zero compatible			
Energy efficiency measures	Cost-negative or cost-neutral	Low (USD 0-50 / tCO_2)	Moderate (USD 50-100 /tCO_2)	High (> USD 100 / tCO_2)	Widespread use in Mongolia	Mature in the region	Emerging technology	Research and development	Unsuitable for project-finance	Significant challenges	Potentially suitable	Highly suitable	Not likely compatible	Inefficient solution	Compatible and/or necessary	**High-hanging fruit projects**
Renovation of the district heating network for energy efficiency		●				●				●					●	
Retrofitting the district heating network for low temperatures	No known estimate High upfront CAPEX						●			●					●	→ ✓
Retrofitting building envelopes for energy efficiency		●				●						●			●	
Building-scale heat supply																
Resistive electric heating (ger districts)	No known estimate					●				●				●		
(Solar-assisted) air-source and ground-source heat pumps			●				●					●			●	→ ✓
District-scale heat supply																
Biomass and waste						●					●		●			
Large-scale solar thermal and solar assisted heat pumps	No known estimate High upfront CAPEX						●				●				●	→ ✓
Green hydrogen							●				●			●		

The assessment of individual measures presented in this Table and on the following pages represents the authors' judgement based on interviews with national experts and literature review. Cost indications are illustrative estimates based on the information available to the authors.

Table 1

Summary of potential climate change mitigation measures and identification of high-hanging fruit projects for building heat in Mongolia

- Building-scale (solar assisted) air-source and ground-source heat pumps
- District-scale heat pumps and solar thermal

We identify these measures as high-hanging fruit projects on account of their low penetration in the Mongolian market and their high cost. These projects would currently be very unlikely to be implemented without external support, even under measures to increase climate change mitigation ambition, since the costs and/or novelty of the technologies means that they are likely beyond reach of unilateral host country ambition raising. This could change in the medium-term, if the increased deployment of these technologies leads to them becoming more accessible.

Despite having higher upfront costs compared to less efficient solutions (such as electric resistive heating) the solar assisted heat pump technologies offer low operational costs which may lead to a lower levelised cost of heating. It could be that the more efficient hybrid systems deliver lower levelised costs over their lifetime, compared to less efficient technologies. The high upfront costs and the lack of experience with the technology thus represent a major barrier for implementation. External support for the piloting and demonstration of building-scale and district-scale heat pumps, solar thermal and hybrid systems could be an important driver to initiate the shift to a low-carbon heating system in Ulaanbaatar, while also contributing to the building of local expertise and awareness.

These measures are explored in further detail in the next pages.

LOW TEMPERATURE DISTRICT HEATING AND SOLAR ASSISTED HEAT PUMP TECHNOLOGIES MAY ALSO REPRESENT HIGH-HANGING FRUIT PROJECTS IN OTHER CITIES IN CENTRAL AND WESTERN ASIA.

The challenges faced in the Ulaanbaatar heating sector are similar to in other parts of the country, as well as in other countries located in cold climates.

The solutions identified here could be especially relevant in other cities with existing district heating networks or the ability to develop such a network. This could include many cities in urban Northern China, where district heating systems already serve a majority of urban heating demand (IEA, 2017). District heating systems face similar challenges in cities throughout Kazakhstan (IEA, 2020), as well as some cities in Kyrgyzstan (World Bank, 2015) and Uzbekistan (TTC and TTE, 2018). There may also be potential for the redevelopment of the dismantled district heating networks in some areas of Georgia (Energy Community, 2022).

ENERGY EFFICIENCY MEASURES ARE ALSO A PREREQUISITE FOR THE IMPLEMENTATION

OF THESE HIGH-HANGING FRUIT TECHNOLOGIES.

While energy efficiency measures for the district heating network and buildings are a prerequisite for the implementation of renewables based heating technologies, we do not classify these technologies as high-hanging fruits on account of their relative accessibility. Due to their lower marginal abatement costs and higher technological maturity, these measures are more likely to access finance through other streams or even to be within reach of the host country in the context of measures to increase climate change ambition, but would be less suitable as carbon crediting projects for offsetting or compliance claims, or for other purposing that require a high guarantee of additionality, compared to the projects marked as high-hanging fruits.

It is nevertheless important to stress the high importance of these measures and their integral role in achieving deep emission reductions in the Ulaanbaatar heating sector. The high upfront capital expenditures associated with these important projects may also represent a barrier for their implementation in the short-term. The large-scale of these infrastructure projects, combined with reasonable cost savings or returns in the longer term, may make such measures more appropriate for large-scale concessional finance towards the host-country's own measures for raising its climate change ambition.

UPGRADING THE DISTRICT HEATING NETWORK FOR LOW TEMPERATURES

Status

The upgrading of existing district heating networks decreases the heat losses and thus saves energy and emissions. Further, a certain modernisation of the district heating network is a prerequisite to efficiently integrate renewable energy-based heating technologies to the system.

Potential & costs

A World Bank financed project is currently modernising parts of the district heating network of Ulaanbaatar, for energy efficiency improvements. The modernisation of district heating systems is practiced globally, yet low-temperature district heating systems remain relatively novel.

The World Bank project for modernising parts if the district heating network aims to reduce GHG emissions by 117 ktCO_2e per year with an initial capital investment of around USD 30 million. Over a 20 year period, this would imply a relatively low marginal abatement cost in the region of USD 15 / tCO_2 for basic energy efficiency modernisations. However, investment costs would increase significantly if larger parts of the network would be upgraded to use a lower supply temperature.

Shah et al. (2020) estimate a cost of approximately USD 0.6 million for the development of a low temperature district heating network for 30 buildings. Extrapolating this estimate to all non-ger buildings in Ulaanbaatar would amount to an illustrative estimate in the order of USD 5 billion USD in upfront capital costs. The lifecycle costs and marginal abatement cost of this investment remain highly uncertain, depending on the costs and performance of associated large-scale heat supply technologies, which are not yet tested in the Mongolian context.

Unlocking action

The majority of heat generation and distribution in Ulaanbaatar is state or municipality owned (Yun Wu et al., no date). The large-scale investments required for upgrading district heating, and the system-wide approach to planning such infrastructure, represent **significant challenges for project-based voluntary climate finance**. For much of the network, it could be challenging to establish practical boundaries for bitesize project interventions. However, there is potential

BUILDING SCALE (SOLAR ASSISTED) AIR-SOURCE AND GROUND-SOURCE HEAT PUMPS

Traditional air-source and ground-source heat pumps have faced limitations in extremely cold environments, but new heat pump technologies and hybrid systems combined with solar collectors can overcome barriers to provide reliable and efficient year-round heating. New two-stage compression air-source heat pumps (ASHP) can provide heat in ambient temperatures down to -40 °C (Pillarisetti et al., 2019). These systems can be combined with solar collectors to overcome potential barriers related to frost formation and to increase efficiency by around 40% (Van D. Baxter, Groll and Sikes, 2017). Solar collectors can also be combined with ground-source heat pumps to overcome the barrier of thermal soil imbalance by injecting thermal energy into the ground, and increasing the system efficiency (Mussard, 2017; Xu et al., 2021).

Status

Commercially available two-stage air-source heat pumps have been successfully demonstrated for a small number of non-insulated buildings in a pilot project in Ulaanbaatar (Pillarisetti et al., 2019), but high upfront investment costs and low awareness means that this remains a novel measure.

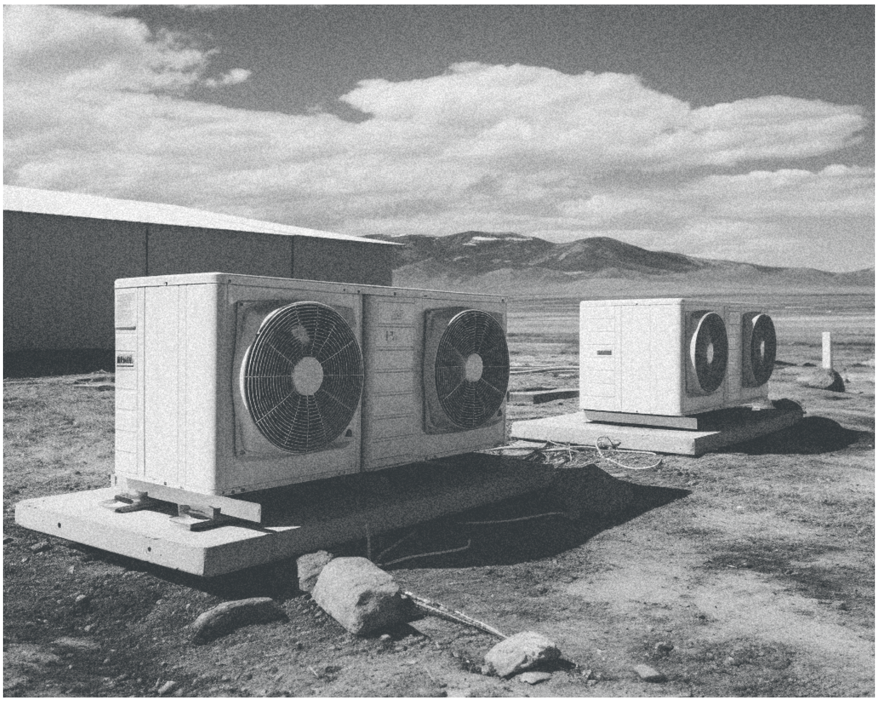
Ground source heat pumps have been applied only sparingly to public buildings in Ulaanbaatar. Pilot projects and simulations for solar assisted ground source heat pumps in Northern China have demonstrated excellent performance in extremely cold temperatures (Wang et al., 2010; Rad et al., 2013; Emmi et al., 2015; Kegel et al., 2016; Mussard, 2017).

Potential & costs

Heat pumps can completely decarbonise heat supply if the electricity generation is renewables based. Ongoing operation costs of pilot projects were found to be 25% more expensive than coal fired heaters, but significantly cheaper than the ongoing costs of resistive electric heaters due to the more efficient energy use (Pillarisetti et al., 2019). Although operational costs can be favourable, the upfront investment costs of these technologies are comparably very high. The upfront costs of solar assisted ground source heat pumps will be considerably higher even than for air-source heat pumps, although the superior efficiency of these systems may mean that the marginal abatement costs over a longer-time period could be similar for both technologies. An analysis of mitigation options for energy in Mongolia classified ground source heat pumps as one of the most expensive technologies, with a marginal abatement cost of approximately USD 60 / tCO_2e (GGGI, 2014). In the absence of more recent data, and given the lack of major developments in the adoption of these technologies in recent years, we speculate that the marginal abatement costs of these technologies may remain in the moderate range of USD 50-100 / tCO_2e.

Unlocking action

The installation of building-scale heat pumps may be highly suitable for voluntary project-based finance. Project-level boundaries for interventions can be easily established in the form of individual buildings, clusters of buildings, or districts, depending on the volume of finance available for the project. Such projects should however not necessarily be considered one-time interventions, but should only be implemented alongside plans for the ongoing servicing and maintenance of technologies, including any necessary training and access to components.



DISTRICT-SCALE HEAT PUMPS AND SOLAR THERMAL

The replacement of CHP with large scale heat pumps and solar thermal could gradually decrease the carbon intensity of the district heating system. By maximising the solar fraction, a significant share of the heat demand could be met directly by solar energy while the remaining demand would be generated by power-driven electric heat pumps. By ensuring that the power feeding the heat pump is generated from renewable sources, the heat supply could be fully decarbonised.

Status

The technical feasibility of heat pumps and solar thermal in the Mongolian context has already been theoretically demonstrated (Pillarisetti et al., 2019; Shah et al., 2020), but large scale hybrid systems still need to be demonstrated. As of 2020, 2.5 MW capacity of ground source heat pumps had been installed in Mongolia, mainly to public buildings in Ulaanbaatar (Savickas, 2020). No large-scale systems have yet been piloted, but their potential has been successfully investigated through simulation modelling (Shah et al., 2020), and the technical feasibility has been proven through pilots in other severely cold locations (Wang et al., 2010; Kegel et al., 2016) (Mussard, 2017). A large-scale solar-assisted ground source heat pump for district heating is tested in the outskirts on Beijing, supplying 181 residential buildings and one public building (Huang et al., 2020).

Potential & costs

Large scale heat pumps coupled with the deployment of renewable-based power generation and energy efficiency measures could have the theoretical potential to completely displace fossil-powered heat generation in Ulaanbaatar's district heating network by 2050, indicating a mitigation potential of up to 14 $MtCO_2$ per year, with a cumulative initial investment cost in the range of USD 5.5-7 billion (Shah et al., 2020). This considers only the upfront costs of the heat supply technologies. Combined with necessary investments in retrofitting the district heating system, and expanding the renewable electricity generation capacity to supply the large-scale heat pumps, the costs may be far higher, but it is also possible that the efficiency of the systems could return a lower levelised cost of heating than other heat supply options, over the project lifetime.

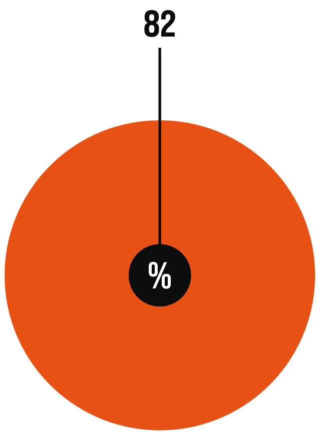
Unlocking action

Because the deployment of low-carbon heating at present is limited in Mongolia, and its integration to district heating systems yet untested, an important first step is the piloting and demonstration of those systems. Doing so could allow for the development of the right skills and awareness around the issue while also testing the technology at a controllable scale. In such projects, the participation of relevant stakeholders such as the district heating operators and distributors, as well as the local and national government could drive an open discussion and the development of a common vision for the heating sector. Finance for large scale renewable energy generation technologies for integration into district heating could be provided through project-based finance, though interventions should not be isolated from system-level planning and should be implemented with the participation of all relevant stakeholders responsible for the operation, upkeep and further development of the district heating system.

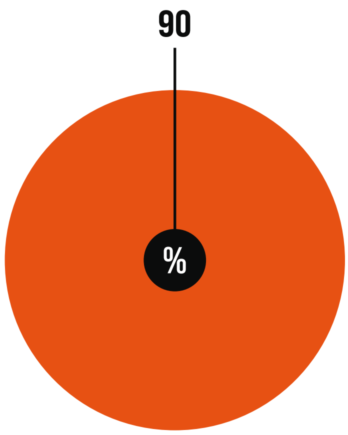
05 HEAVY-DUTY TRANSPORT IN INDONESIA

Energy consumptions and emissions from Indonesia's transport sector have sharply increased due to rapid economic growth, urbanisation, and private vehicle ownership.

Indonesia's transport system is highly concentrated on road transport and private and fragmented modes.



Proportion of road passenger transport emissions from over 120 million motorcycles in 2018.



Proportion of freight trips carried out by road, by over one million private trucking companies.

Decarbonisation depends on centrally planned infrastructure developments for modal shift and electrification, but high-hanging fruit demonstration.

Electrific inner- and inter-city buses are a demonstrated technology in Indonesia, although costs remain high, and they remain in the early stages of adoption. Projects aiming to trial electric buses in Indonesian cities could accelerate the transition.

Electrification of small and medium-sized passenger and freight watercraft can be a particularly relevant technology to demonstrate in the archipelago nation of Indonesia, with hundreds of formal ferry connections and vast potential for community-scale projects.

Electrification of medium and heavy-duty freight trucks could significantly reduce the emissions from freight transport. Demonstration projects for commodities transported on short distance routes and fixed corridors could be a steppingstone to centralised large-scale infrastructure development.

5.1 EMISSION DRIVERS AND DECARBONISATION CHALLENGES

ENERGY CONSUMPTIONS AND EMISSIONS FROM INDONESIA'S TRANSPORT SECTOR HAVE SHARPLY INCREASED DUE TO RAPID ECONOMIC GROWTH, URBANISATION, AND PRIVATE VEHICLE OWNERSHIP. URBAN PUBLIC TRANSPORT, ELECTRIFIED VEHICLE FLEETS, AND EXPANDED RAIL INFRASTRUCTURE COULD SIGNIFICANTLY REDUCE EMISSIONS IF POWERED WITH RENEWABLE ENERGY.

The transport sector accounted for 158 $MtCO_2e$ or 17% of Indonesia's total national GHG emissions (excl. LULUCF) in 2019 (MEF, 2021). In 2021, the sector accounted for 46% of final energy consumption, almost all from petroleum oil (MEMR, 2022).

In 2019, approximately 62% of Indonesia's GHG emissions from transport corresponded to passenger transport, and 38% to freight transport (NewClimate Institute, 2019). Direct energy consumption by the transport sector has increased significantly over the last decade, growing at an average rate of 3.7% per year from 2011 to 2021. This is a consequence of rapid economic growth, subsidised fuel, and rapid increase in personal vehicle ownership (mostly motorcycles) (Siagian et al., 2015). Indonesian cities are growing faster than others in Asia—68% of the population could be living in cities by 2025 (The World Bank, 2016), and the vehicle fleet is expected to double by 2035, compared to 2010 (NAMA Facility, 2017).

The Climate Action Tracker found that emissions from road and rail transportation in Indonesia would nearly double between 2015 and 2050 under the current development scenario (CAT, 2019). In contrast, scenarios that are compatible with the 1.5°C goal of the Paris Agreement would nearly completely decarbonise the passenger road and rail transport sectors by 2050 (95% reduction in comparison to 2015).

URBAN MOBILITY IN INDONESIA FACES SIGNIFICANT CHALLENGES OWING TO A STEEP INCREASE IN URBANISATION AND HISTORICALLY LOW INVESTMENTS TO MEET THIS DEMAND. MOST PEOPLE IN CITIES USE PERSONAL VEHICLES, MAINLY TWO-WHEELERS, AND THERE IS LIMITED PROGRESS WITH THE ELECTRIFICATION OF THE LIGHT-DUTY VEHICLE FLEET. WHILE MANY CITIES HAVE ADOPTED BRT SYSTEMS, ONLY JAKARTA HAS URBAN RAIL.

Private light-duty vehicles is the main mode of urban transport in Indonesian cities, causing congestion, pollution, loss of public space, and an overall decline in urban living conditions (Leung, 2016). In 2018, there were 120 million motorcycles and 16 million passenger cars in Indonesia; motorcycles emit approximately 82% of road passenger transport emissions (Adiatma and Marciano, 2020). The main lever in reducing these emissions is the electrification of the personal vehicle fleet—fossil fuel-based vehicles would need to stop being sold between 2035 and 2040, and the whole passenger road vehicle fleet (cars, motorcycles, and buses) should be electric by 2050 (CAT, 2019). Currently, the number of electric cars and two-wheelers remains low, despite several policies implemented or planned to accelerate the transition (Arinaldo et al., 2021). The potential that the electrification of transport has to reduce emissions crucially depends on the emission intensity of the electricity grid (CAT, 2019), but Indonesia's transition to renewable-based power generation is not advancing at the necessary pace (Arinaldo et al., 2021); the country expects to meet 64% of its power demand in 2030 with coal (CAT, 2021; Republic of Indonesia, 2021).

Shifting urban passengers from private vehicles to non-motorised transport (NMT) can reduce emissions in the transport sector, but NMT infrastructure remains relatively undeveloped in Indonesian cities. NMT in Indonesia includes cycling, walking, pedicabs ("becaks"), and horse carts ("delmans") (Sufa et al., 2020b). In 2020, Indonesia approved the National Vision for Non-Motorised Transport, a guide for city governments to prioritise the needs of pedestrians and cyclists (UNEP, 2020). Some of the problems identified in this guide include the lack of an integrated network of sidewalks, slippery or damaged sidewalks, the lack of crosswalks, low accessibility for people with disabilities, and the lack of bicycle paths (Sufa et al., 2020a).

The improvement and expansion of public transport is a crucial measure to limit the impacts of congestion in Indonesian cities. Currently, public transport is only used in a minority of urban trips and is mostly based on buses, as 16 cities in Indonesia have semi-bus-rapid-transit (BRT) systems (Leung, 2016). Jakarta has the world's longest-running BRT system with segregated lanes (Transjakarta), with 13 lines covering 251 km (Transjakarta, no date). The Indonesian government aims to support cities in the development of BRT; through international cooperation, feasibility studies are being carried out in five cities, and funds from the World Bank and local governments have been secured for some projects (Rahman, 2021). Several cities are planning to introduce electric buses to the public transport fleet (Thorn, 2021), with Transjakarta incorporating 30 electric buses in March 2022 (The Jakarta Globe, 2022). In contrast, urban rail is underdeveloped in Indonesia, with few cities offering commuter train services (Leung, 2016). Jakarta is the only city to have a rail-based Mass Rapid Transit system, whose first line was inaugurated in March 2019 (CPI, 2019).

Inter-city public transport in Indonesia is mostly by bus, operated by many private and public companies. Inter-city trains run by a public operator are also used. Although they have limited geographical coverage, investments are being made to develop inter-city train connections.

STATE-OWNED COMPANIES, PRIVATE COMPANIES AND COMMUNITY-BASED SOLUTIONS OFFER TRANSPORTATION SERVICES THAT CONNECT DIFFERENT CITIES AND REGIONS IN INDONESIA, BY ROAD, RAIL, WATER, OR AIR.

Buses are the main mode of inter-city transportation in Indonesia, especially in Java and Sumatra (Sinaga, 2014; Angloinfo, 2023). They travel within islands or even across islands by using ferry crossings. In Java, demand is high for inter-city travel along the island’s East-West corridor; an increase in bus travel occurred after the completion of the Trans-Java Toll road network, which runs for 1,167 km and connects several major cities across the corridor while bypassing urban areas (Radityasani, 2020).

Inter-city passenger rail services are offered by the state-owned company PT Kereta Api Indonesia (“Indonesian Railways Company”) and cover all provinces in Java and some provinces in Sumatra (MoT, no date). Rail travel is limited by infrastructure and is used in only 6% passenger trips in Java (Sinaga, 2014). However, the Indonesian government is aiming to extend the railway network to 10,524 km by 2030, from the current 7,032 km, to improve inter-city connections (New Straits Times, 2022). Expansion plans also include upgrading single-track railways to double tracks, electrifying the main lines, and upgrading selected corridors to high speed rail (Nirmala, 2021; Rogers, 2022). Investments are also underway to extend the railway in Sumatra (New Straits Times, 2022), and in Sulawesi where a 2,000-km trans-Sulawesi railway network is under construction (Fatir, 2022)

Water-based passenger transportation in Indonesia consists of ferries that connect islands, and longboats that sail on inland waterways. Ferry transportation, including car ferries, run frequently between the stretch of islands between Sumatra and Java and are operated by both public and private companies (Aarons, 2023). The biggest operators are state-owned enterprises Pelni and ASDP. Improvements to sea passenger transport are part of the government’s Marine Highway project, with which it aims to facilitate better connections between eastern and western Indonesia by providing more vessels and more regular schedules (ERIA et al., 2022). In addition to maritime transport, inland waterways provide transportation in the absence of roads and railways in some areas of the country (Sehlleier et al., 2017).

The air passenger transport sector in Indonesia has grown considerably in the last 20 years, with over 60 commercial airlines transporting approximately 79.5 million domestic passengers between Indonesian islands and cities in 2019

(Minx et al., 2022)(Aarons, 2023). The country has the seventh-fastest-growing aviation industry, and it ranks second to China in terms of aircraft orders and business value (ITA, 2022). As long as air travel keeps serving the increasing demand of inter-city travel, emissions from the sector will increase. The potential of sustainable aviation fuels to reduce air travel emissions is constrained by the limited supply of renewable energy and biomass for their production. Therefore, demand management measures, such as shifting air travel to other modes like electrified road or rail, would be necessary to reduce aviation emissions (CAT, 2022).

MOST FREIGHT IN INDONESIA IS TRANSPORTED WITH EMISSION-INTENSIVE TRUCKS THAT OPERATE IN A FRAGMENTED MARKET, WHILE FOSSIL FUEL-POWERED VESSELS OPERATE INTER-ISLAND ROUTES. EMISSION REDUCTIONS IN FREIGHT TRANSPORT COULD BE ACHIEVED BY SHIFTING FREIGHT FROM TRUCKS TO RENEWABLE-POWERED RAIL AND BY TRANSITIONING TRUCKS AND VESSELS TO ZERO-CARBON FUELS.

Freight transport in Indonesia is mostly road based; 90% of freight trips (tkm) are done by truck, 9% by shipping, less than 1% by rail, and less than 0.1% by air (Breemersch et al., 2019). The low share corresponding to shipping indicates that most freight transport occurs within rather than between islands. Almost 90% of freight transport occurs in the island of Java, where most people live and economic activity is centred (around 60% of national GDP) (Sehlleier et al., 2017).

Freight road transport accounted for approximately 37% of Indonesia's transport emissions in 2019 [Prospects]. The truck fleet in Indonesia is old and emission intensive; approximately half of trucks are older than 20 years (Agustinus and Fitriyani, 2019; Yang et al., 2021). Fuel and vehicle standards are limited in Indonesia—the latest vehicle standard to be introduced was Euro IV in 2021, 11 years after China and 3 years after Vietnam (Yang et al., 2021). Trucks mostly use local roads instead of toll roads (Yang et al., 2021), which increases fuel consumption and maintenance costs (Breemersch et al., 2019). Logistics could be optimised, as trucks travel with an empty load for around half of their journeys. The modernisation of the trucking fleet faces coordination and financing challenges. The trucking sector in Indonesia is composed of over one million trucking companies, of which most own one to five vehicles; for these small operators, investing in new truck technologies is generally unfeasible, as they operate on thin profit margins that are even thinner for older trucks (Bennis and Van Tuijll, 2016). Interest rates offered by truck leasing companies are particularly high, exacerbating the barriers for more modern, expensive and lower-emitting technologies (Yang et al., 2021).

Rail is currently used only in 1% of freight trips, as it is underdeveloped across Indonesia (Sehlleier et al., 2017). In Java, only 49% of the railroad track length is integrated as a network, and in Sumatra the tracks are in three separate regions. Moreover, the tracks have a low rail weight and carrying capacity (axle load tolerance is 9-18 tonnes, compared to 22.5–30 tonnes in Europe), which limit the transport capacity of the network (Woroniuk et al., 2014). Despite the historic lag in rail infrastructure development, new tracks have been completed in recent years in the island of Java. In 2014, a double track network of 727 km in northern Java tripled the number of freight train trips (Susantono, 2013), and it reached 47% of its transport capacity by 2016 (Breemersch et al., 2019). KALOG, a state-owned enterprise, began operations of a new train service in southern Java in 2016 increasing the carrying capacity of both the North Java Corridor and the northern Solo Senja Utama train. These improvements led to a 16% overall increase in total weight of commodities transported by rail from 2014 to 2018, including coal, fertiliser, cement, and fuel (Breemersch et al., 2019). There remains significant potential for the further shift from road to rail for steel, port-related containers, cement and cars, since the transport of these commodities is highly concentrated on specific corridors across the country (Breemersch et al., 2019). An efficient shift towards rail would require investments beyond the expansion or reactivation or rail networks, as there is a lack of infrastructure and logistical coordination for inter-modal transfer (i.e., transferring cargo from ships and trucks to trains).

Maritime freight transportation accounts for 9% of domestic freight transport activity in Indonesia (Sehlleier et al., 2017). Indonesia is an archipelagic nation with over 6,000 populated islands and approximately 100 commercial ports, most of which serve domestic (inter-island) routes covered by small vessels and few have container facilities that would allow the transport of large volumes of cargo (Leung, 2016). Inter-island shipping is estimated to account for 300 million tonnes, ~60% of the total cargo transported by sea in Indonesia; the rest accounts to international shipping, which is handled by four large ports located in Jakarta, Surabaya, Medan, and Makassar (Sehlleier et al., 2017). Community boat services for short-sea shipping support the livelihoods of rural communities on the coast and consist of traditional pinisi wooden sailing boats, often modernised with diesel engines (Leung, 2016). Vessels operating in Indonesia are emissions intensive, and the government has expressed willingness to transition the shipping sector to using low-emission fuels (Junida and Ihsan, 2021). Battery-based propulsion systems may be feasible for small vessels, while larger vessels and international ships are more suited to green ammonia or hydrogen (Carpenter-Lomax et al., 2021). Indonesia could transition its fleet of large vessels (tankers, bulk carriers, etc.) to green hydrogen and ammonia by harbouring the country’s large renewable energy potential, estimated at around 1,800 TWh. However, the country is on a trajectory of slow adoption of renewable energy technologies. Small vessels that support local economies could be decarbonised through conversion to battery power technologies and the installation of renewable energy microgrids.

5.2 POTENTIAL CLIMATE CHANGE MITIGATION MEASURES

This section provides an overview of the various potential climate change mitigation measures for selected transport sector measures in Indonesia, to identify potential high-hanging fruit projects and options for supporting measures that are potentially more accessible.

→ **Table 2** presents a summary of the extent to which a range of measures fulfil the criteria to be considered high-hanging fruit projects. We have looked at a non-exhaustive selection of measures for inner-city passenger transport, inter-city passenger transport, and freight transport. Measures exclusively related to regulation that are not relevant for project-based finance – such as vehicle emission standards, mandatory vehicle roadworthiness test, or tax incentives for EVs – are not considered.

The assessment of individual measures presented in → **Table 2** and in the following pages represents the authors' judgement based on interviews with national experts and literature review.

THE DECARBONISATION OF INDONESIA'S TRANSPORT SECTOR REQUIRES CENTRALLY PLANNED INFRASTRUCTURE DEVELOPMENTS FOR MODAL SHIFT AND ELECTRIFICATION, BUT HIGH-HANGING FRUIT DEMONSTRATION PROJECTS CAN PLAY AN IMPORTANT ROLE TO KICK-START THE UPTAKE OF TECHNOLOGIES.

→ **Table 2** identifies the following measures as high-hanging fruit projects in the Indonesian context.

- Electrification of inner-city or inter-city passenger transport buses
- Electrification of small and medium-sized passenger and freight watercraft
- Electrification of medium and heavy-duty freight trucks

These are identified as high-hanging fruit technologies in the Indonesian context on account of their high costs and low market penetration: electrified buses are emerging in Indonesia but electrified watercraft or freight vehicles are not yet in use in the country.

The electrification of heavy transport in Indonesia is not necessarily conducive for project-scale finance; it will require centrally planned infrastructure for the expansion and upgrade of the electricity grid, expansion or renewable electricity

	Marginal abatement cost				Maturity and availability				Suitability of project-finance				Net-zero compatible			
Inner-city transport	Cost-negative or cost-neutral	Low (USD 0-50 / tCO_2)	Moderate (USD 50-100 /tCO_2)	High (> USD 100 / tCO_2)	Widespread use in Mongolia	Mature in the region	Emerging technology	Research and development	Unsuitable for project-finance	Significant challenges	Potentially suitable	Highly suitable	Not likely compatible	Inefficient solution	Compatible and/or necessary	**High-hanging fruit projects**
Infrastructure for non-motorised transport and mobility		●			●				●						●	
Infrastructure and services for electric vehicles		●		●		●			●						●	
Electrification of urban buses						●					●				●	→ ✓
Expansion of urban mass transit		●				●				●					●	
Inter-city transport																
Expansion of inter-city rail	No known estimate High upfront CAPEX.				●				●						●	
Electrification of inter-city buses				●			●			●					●	→ ✓
Electrification of small and medium-sized passenger watercraft			●				●					●			●	→ ✓
Sustainable aviation fuels	No known estimate.					●				●				●		
Freight transport																
Improve infrastructure for intermodal freight transport	No known estimate High upfront CAPEX.					●			●						●	
Upgrade and expansion of freight rail capacity	No known estimate High upfront CAPEX.					●			●						●	
Optimisation of trucking loads	●					●				●					●	
Electrification of medium and heavy duty freight trucks				●			●				●				●	→ ✓
Hydrogen based large watercraft	No known estimate High upfront CAPEX.						●		●						●	

Table 2

Summary of potential climate change mitigation measures and identification of high-hanging fruit projects for heavy-duty transport in Indonesia

The assessment of individual measures presented in this Table and on the following pages represents the authors' judgement based on interviews with national experts and literature review. Cost indications are illustrative estimates based on the information available to the authors.

generation capacity, and charging infrastructure, among other infrastructural challenges. However, project finance can play a role to accelerate the onset of this transition through demonstration projects in closed boundary environments that do not depend on national infrastructure developments, such as transport routes confined to a fixed corridor between two fixed points. Demonstration projects could span a range of scales, from off-grid community-level projects combined with mini-grids, to the introduction of medium-sized inter-island e-ferries combined with charging infrastructure in ports.

These measures are explored in further detail in the next pages.

DEMONSTRATION PROJECTS FOR THE ELECTRIFICATION OF HEAVY-DUTY TRANSPORT WOULD ALSO CURRENTLY BE LIKELY TO REPRESENT HIGH-HANGING FRUIT PROJECTS IN OTHER COUNTRIES, ALTHOUGH SUCH PROJECTS SHOULD BECOME MORE ACCESSIBLE IN THE MEDIUM-TERM.

The rationale for the identified measures to constitute high-hanging fruit projects in the Indonesian context currently holds for many countries. In North America, Europe and China, heavy duty BEVs are beginning to emerge, but in other regions the level of penetration remains very low. Heavy duty BEVs should become more accessible in the medium-term, as their lifetime costs move towards parity with new ICE technologies, as some analysts forecast within the next 5 years. However, these technologies may remain prohibitively expensive in countries where a large proportion of the vehicle stock derives from imported used vehicles.

INFRASTRUCTURE FOR MODAL SHIFT AND ELECTRIFICATION OF LDVS ARE IMMEDIATE PRIORITIES FOR DECARBONISATION OF TRANSPORT IN INDONESIA; THESE MEASURES MAY BE COMPARATIVELY MORE ACCESSIBLE, BUT DEPEND ON LARGE-SCALE FINANCING FOR INFRASTRUCTURE.

Infrastructure and services for non-motorised transport, expansion of rail and public transport systems, and the electrification of light duty vehicles are immediate priorities for the decarbonisation of the transport system in Indonesia. We do not identify these measures as potential high-hanging fruit projects, but rather we consider that such developments could be supported through government spending and multilateral concessional finance, given the very large upfront capital expenditures combined with the relatively accessible marginal abatement costs of these measures.

ELECTRIFICATION OF INNER-CITY AND INTER-CITY BUS TRANSPORT

The electrification of the bus fleet can decarbonise the passenger transport sector on inner-city routes, and potentially short distance inter-city routes. The emission reduction potential depends on the parallel expansion and decarbonisation of the electricity grid.

Status

Public transport in Indonesia is predominantly based on buses, and many cities operate BRT systems. Electric buses have just been recently introduced in the country, albeit exclusively in Jakarta, where 30 buses were added to the Transjakarta fleet in 2022 (CFF, 2021; The Jakarta Globe, 2022). Jakarta has set the goal to electrify its full bus fleet by 2030, while other cities have also shown interest in electrifying their fleets and some have trialled electric buses. Transjakarta has also signed an agreement to run a pilot to retrofit existing buses from having combustion to electric motors (Jakarta Globe, 2022). There are no known examples of inter-city bus transport being electrified in Indonesia.

Potential & costs

Electric buses charged with renewable electricity have a lifecycle GHG intensity of just 10 gCO_2e per passenger-km, while this is 20–50 gCO_2e for diesel buses. The introduction of 100 buses to the Transjakarta fleet has the potential to reduce an estimated 3,349 tCO_2e per year at a cost of USD 37.4 million (GIZ, 2022). While this indicates a very high marginal abatement cost for this pilot project, this includes the cost of necessary related electrification; marginal abatement costs for further expansion of this particular project would likely be lower.

Unlocking action

Electric buses have been demonstrated to be a feasible technology for inner-city transport in the Indonesian context, although costs remain high and they remain in the early stages of adoption. To accelerate the transition, additional funding could be channelled to projects aiming to trial electric buses in Indonesian cities.

The electrification of inter-city travel is more complex; this would depend on a centralised plan for the installation of charging infrastructure in and between multiple cities, and a mechanism to channel financial support to a highly fragmented market of public and private inter-city bus operators.

ELECTRIFICATION OF SMALL AND MEDIUM-SIZED VESSELS

The full electrification of small and medium-sized vessels for passengers and freight can reduce the emissions associated with domestic maritime transport. The emission reduction potential depends on the parallel expansion and decarbonisation of port and/or community scale renewable electricity generation and charging infrastructure. It is estimated that more than 700 thousand small vessels transport goods and people in small communities and support local fishing economies. The diesel-based motor of these vessels could be converted to electricity propulsion, and microgrids could be installed to provide renewable power to the vessels in locations that are not connected to the grid (Carpenter-Lomax et al., 2021).

Status

There is currently no known electrification of small- and medium-sized vessels operating in Indonesia. The Indonesian government is implementing the Sea Highway Programme, which aims to improve connectivity between Eastern and Western Indonesia and between main and remote islands (ERIA et al., 2022). The programme intends to improve ferry connectivity with more vessels and more frequent connections, but no provisions for electrification are currently foreseen (Jelita, 2020). E-ferries have been deployed already in several countries. Norway initiated the electrification of its ferry fleet in 2015 and leads globally in e-ferry deployment (Polly Bindman, 2023). In Thailand, 27 small e-ferries are planned operate along the Chao Phraya River (ADB, 2022). India is also planning the launch of 23 e-ferries to connect several islands to the port city of Kochi (Energy, 2020; The Hindu, 2022).

Potential & costs

Although the initial investment for an e-ferry is large, lifecycle costs are lower than those of conventional vessels. 27 small e-ferries operating along the Chao Phraya River are estimated to reduce emissions by up to approximately 19 ktCO_2e per year, at a cost of approximately USD 18 million (ADB, 2022), indicating a moderate marginal abatement cost in the range of USD 50-100 / tCO_2e over a period of 10-15 years. There are no known estimates for costs associated with micro-scale projects for community vessels combined with community mini-grid infrastructure, but the electricity demand of electrified small vessels could significantly improve the economic feasibility of mini-grids in off-grid locations where demand and readiness-to-pay is often a limiting factor.

Unlocking action

Current government objectives to upgrade and expand marine connectivity may present a conducive context for introducing electrified vessels to Indonesia. With hundreds of formal ferry connections, many of which span only short distances, opportunities may exist for demonstration projects of various scales. For e-ferries to be a successful measure to reduce shipping emissions, such projects should include the necessary installation of charging infrastructure and renewable energy generation capacity: in many areas where community-scale connections operate there is not a reliable grid connection, while even in areas with a reliable grid connection the country's electricity grid remains highly dependent on fossil fuels.

ELECTRIFICATION OF MEDIUM AND HEAVY DUTY FREIGHT TRUCKS

The electrification of trucks could significantly reduce the emissions from fuel combustion in the Indonesian freight transport sector, which is mostly road based and dependent on old, emission-intensive trucks. The emission reduction potential depends on the parallel expansion and decarbonisation of the electricity grid and charging infrastructure.

Status

Electric medium and heavy-duty trucks are an emerging technology option in some countries. Although stocks of electric trucks remained modest in China (ca. 200,000), Europe (139,000) and North America (91,000) in 2022, market analysts have estimated global BEV medium and heavy duty truck shipments to increase from less than 300,000 units in 2022 to approximately 12 million units per year by 2030 (Sustainable Truck and Van, 2022).

Although the Indonesian government has set targets for the electrification of the personal vehicle fleet, such as cars and motorcycles, there is no vision for the electrification of trucks yet, and there are no known examples of electrified trucks operating in Indonesia.

Potential & costs

Trucks in Indonesia are responsible for 23% of transport energy demand and are estimated to emit 58 $MtCO_2e$ annually. The emissions abatement cost for heavy-duty BEV trucks has been estimated to be in the hundreds of USD per tonne of CO_2e (Jaramillo et al., 2022). Upfront costs for an electric semi-truck have been estimated at around USD 400k in the US, but prices as low as USD 180k have been advertised for new models (Buysse, 2022). In China, where upfront and operating costs are lower, the cost of owning and operating a BEV straight truck is estimated reach parity with diesel trucks by 2026, and semi-trailer trucks by 2029 (Shiyue Mao, Hussein Basma, Pierre-Louis Ragon, Yuanrong Zhou, 2021).

Unlocking action

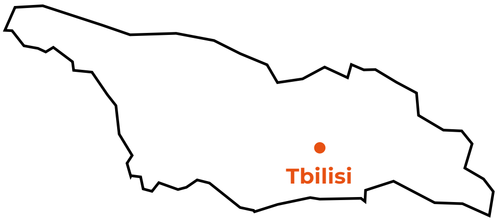
A truck replacement programme in Indonesia entails significant challenges for project-based finance: such a programme would likely depend on a centralised plan for the installation of charging infrastructure, and a mechanism to channel financial support to a highly fragmented market of over one million truck operators operating very small fleets.

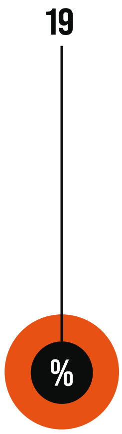
A steppingstone which could be accessible to project-scale finance, would be the installation of demonstration projects for commodities transported on short distance routes and fixed corridors, where charging infrastructure would only be required at the origin and destination. This could include for example, short-distance freight corridors between major factories or industrial parks and nearby ports.

06 AGRICULTURE IN GEORGIA

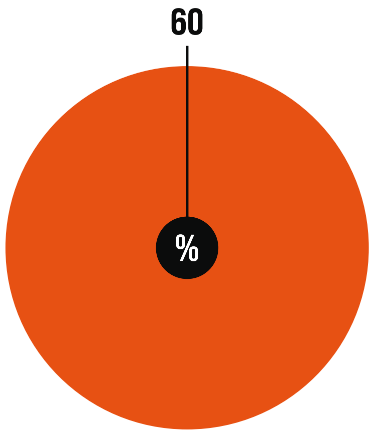
The agriculture sector in Georgia represents an especially challenging and increasing source of emissions.

Georgia is in the process of modernising and commercialising the agriculture sector to increase productivity and profitability.





Proportion of national GHG emissions accounting to the agriculture sector in 2015.



Projected increase in emissions from soils between 2015 and 2030.

High-hanging fruit projects can support the emergence of new technologies and measures for deep emission reductions in croplands.

Electrified farm machinery can decarbonise agricultural energy but is not yet available on the Georgian market.

Soil and plant microbiome technologies can enhance carbon sequestration and reduce nitrous oxide emissions, but the import of microbiome inputs is expensive and these are not yet adapted to local crops.

New perennial grain crops can enhance carbon sequestration and decrease soil erosion, but research and development is needed to adapt these crops to the Georgian context.

6.1 EMISSION DRIVERS AND DECARBONISATION CHALLENGES

GEORGIA IS IN THE PROCESS OF MODERNISING AND COMMERCIALISING THE AGRICULTURE SECTOR TO INCREASE PRODUCTIVITY AND PROFITABILITY. MUCH OF THE SECTOR IS STILL CHARACTERISED BY SMALL-SCALE AND LABOUR INTENSIVE FARMING OPERATIONS.

In 2020, the agriculture sector employed around 40% of the Georgian population, most of them are categorized as “self-employed” which usually means that they are small-scale subsistence farmers. However, the sector’s contribution to national GDP has been declining, from 25% in 1999 to 8.4% in 2020 (GEOSTAT, 2022). 43% of Georgia’s total land area is agricultural land, including 324,000 ha of arable land, 120,800 ha of permanent crops and roughly 2 million ha of pasture and meadows (FAOSTAT, 2021).

The current government is projecting a rise in production levels mainly due to the expected development of large-scale commercial agriculture, making it crucial to embed sustainable business practices from the beginning onwards to ensure a sustainable long-term pathway for the sector (Winrock and Remissia, 2017). Various projects are now in place to help make the Georgian agriculture sector more productive and profitable.

EMISSIONS FROM THE AGRICULTURE SECTOR ACCOUNT FOR A FIFTH OF GEORGIA’S TOTAL NATIONAL GHG EMISSIONS AND ARE PROJECTED TO INCREASE BY APPROXIMATELY 40% BETWEEN 2015 AND 2030, MOSTLY DUE TO INCREASED EMISSIONS FROM AGRICULTURAL SOILS.

The agriculture sector accounted for approximately 19% of GHG emissions (3.31 MtCO2e) in 2015. In 2015, emissions from enteric fermentation accounted for the majority of the sector’s GHG emissions (44%), followed by emissions from agricultural soils and manure management, accounting for 41% and 14% of emissions, respectively (MEPA, 2019). Energy-related emissions represented just about 1% of the sector emissions, excluding emissions from agricultural vehicles (e.g., tractors and others), which are currently accounted within the Climate Strategy and Action Plan under the transport sector, under “off road vehicles”.

Under the reference scenario projected for Georgia’s 2021-2030 Climate Strategy and Action Plan (MEPA, 2021; Day et al., 2022), **emissions from the agriculture sector are projected to increase by approximately 40% to 4.623 MtCO$_2$e in 2030** compared to 2015 levels.

Emissions from agricultural soils are projected to increase by 60% between 2015-2030 and account for the majority of the overall projected growth in sector emissions. The main source of agriculture soil emissions projected for 2030 are pasture range and paddock with 32% of total soil emissions (2015: 29%), nitrogen leaching and runoff with 26% (2015: 31%), and the use of synthetic fertilizers with 19% (2015: 23%).

The anticipated industrialisation of livestock farming is also projected to drive a growth of emissions from the livestock sector. Enteric fermentation emissions are projected to increase by 17% between 2015 and 2030, while emissions from manure management increase by 47%. Cattle was the source of 92% of emissions from enteric fermentation and 82% of emissions from manure management in 2015 and would remain the major source of these emissions up to 2030 (Winrock and Remissia, 2017).

6.2 POTENTIAL CLIMATE CHANGE MITIGATION MEASURES

This section provides an overview of the various potential climate change mitigation measures from the agriculture sector in Georgia, to identify potential high-hanging fruit projects and options for supporting measures that are potentially more accessible.

→ **Table 3** presents a summary of the extent to which a range of measures fulfil the criteria to be considered high-hanging fruit projects. We have looked at a non-exhaustive selection of potential supply side-measures for climate change mitigation from the livestock sector and from cropping systems. Demand-side measures are not considered in this section, despite their fundamental importance for the transition of the agriculture sector, due to the complexity of such measures for project-based finance which this report is focused on.

The measures are presented in further detail in the following pages.

The assessment of individual measures presented in → **Table 3** represents the authors' judgement based on Climate smart agriculture practices in the context of Georgia's climate mitigation efforts (Day et al., 2022), which was compiled through interviews with national experts and literature review (WRIGHT, 2004; Makundi and Sathaye, 2004; OECD, 2006; Smith et al., 2007; Chatterjee and Lal, 2009; FAO, 2009, 2020; McKinsey & Company, 2009; Pratt and Moran, 2010; Teichmann, 2015; Zhang et al., 2015; Muller et al., 2016; Winrock International, 2017; Hu et al., 2017; Ministry of Agriculture and LTD Georgian Amelioration, 2017; Harmsen, 2019; Ahmed et al., 2020; National Statistics Office of Georgia, 2020; World Bank, 2020, 2022; Zaidi et al., 2020).

	Marginal abatement cost				Maturity and availability				Suitability of project-finance				Net-zero compatible			
	Cost-negative or cost-neutral	Low (USD 0-50 / tCO_2)	Moderate (USD 50-100 /tCO_2)	High (> USD 100 / tCO_2)	Widespread use in Mongolia	Mature in the region	Emerging technology	Research and development	Unsuitable for project-finance	Significant challenges	Potentially suitable	Highly suitable	Not likely compatible	Inefficient solution	Compatible and/or necessary	High-hanging fruit projects
Cropping systems																
Zero emission machinery				●			●					●			●	→ ✓
Low tillage*	●				●						●				●	
Plant management*		●			●						●				●	
Water management*						●					●				●	
Synthetic fertilizer management	●					●					●				●	
Organic production*		●			●						●				●	
Biochar application*	●						●				●				●	
Agroforestry*	●				●						●				●	
Microbiome technology*	Unknown							●			●				●	→ ✓ Mostly CDR
Perennial grain crops*	Unknown						●	●			●				●	→ ✓ Mostly CDR
Livestock																
Grazing land management		●			●				●					●		
Livestock manure management		●				●						●		●		
Livestock feeding optimisation			●			●					●			●		
Breeding optimisation	●						●				●			●		
Health and disease prevention	●					●					●			●		
Direct methane capture		●					●				●			●		
Advanced inhibition of EF	Unknown							●	●					●		

Table 3

Summary of potential climate change mitigation measures and identification of high-hanging fruit projects for agriculture in Georgia

* Some of the cropping system measures are related mostly to enhanced but non-permanent carbon dioxide removals (CDR) and storage, rather than the direct reduction of GHG emissions. These projects may not be relevant for offsetting claims on account of the non-permanence of their impacts, but can still be considered as high-hanging fruit projects for supporting through climate contributions **(see Section A1.2 and → Section A1.3)**

The assessment of individual measures presented in this Table and in the following pages represents the authors' judgement based on interviews with national experts and literature review. Cost indications are illustrative estimates based on the informational available to the authors.

HIGH-HANGING FRUIT PROJECTS ARE IDENTIFIED FOR CROPLAND AGRICULTURE IN GEORGIA, BUT NOT ALL OF THESE MEASURES WILL BE SUITABLE FOR CARBON CREDITING MECHANISMS.

→ **Table 3** identifies the following measures as high-hanging fruit projects in the Georgian context. These measures are explored in further detail in the next pages.

- Electrified farm machinery
- Soil and plant microbiome technology
- New perennial grain crops

We identify these four measures as high-hanging fruit projects on account of their current inaccessibility in the Georgian context; none of these solutions are currently available on the Georgian market.

For microbiome technologies and new perennial grain crops, the mitigation potential of these measures may be very significant, but this remains uncertain due to the early stage of research and development and uncertainty regarding how global solutions will fare in the Georgian context. For some of these more innovative measures in cropping systems, Georgia could benefit from participating in global research programmes, in order to support an increased understanding on the local suitability of solutions that emerge, and to lead more quickly to the development of more locally appropriate options. Project-based finance delivered through a climate contribution model that is not attached to carbon crediting mechanisms could be an effective means of supporting the next steps for Georgian participation in R&D programmes, locally-specific R&D, and pilot projects to test emerging locally-specific solutions. But the suitability of these measures for project-based finance through carbon crediting may be limited. More research and development is likely necessary on the local level before projects can be implemented, making these measures currently somewhat unsuitable for carbon crediting mechanisms that depend on quantifiable emission reduction outcomes. The non-permanence of carbon dioxide removal outcomes also makes some of these projects unsuitable for offsetting or compliance claims, even once those outcomes can be quantified **(see → Section A1.2)**.

MORE ACCESSIBLE TECHNOLOGIES AND PRACTICES ALSO HAVE SIGNIFICANT POTENTIAL FOR FURTHER EMISSION REDUCTIONS.

Most of the measures presented in → **Table 3** for livestock and cropping systems are in theory more readily accessible due to their lower marginal abatement costs and their maturity in Georgia or neighbouring countries.

However, none of the measures assessed in this section are standard practice within Georgia, and their widespread implementation is also not planned as a key component of Georgia's 2021-2030 Climate Strategy and Action Plan, which is the implementation blueprint for Georgia's NDC. There is significant potential for technical or financial support to reduce emissions and support Georgia to increase ambition through these measures, as long as that support is not associated with offsetting or compliance claims or otherwise dependent on a high guarantee of additionality.

MANY CLIMATE SMART AGRICULTURE PRACTICES ON CROPLANDS COULD BE UNLOCKED THROUGH BETTER LAND TENURE REGULATION ALONGSIDE AWARENESS AND EDUCATION PROGRAMMES.

Many of the measures associated with more sustainable land management – which low tillage, plant and water management, synthetic fertilizer management, organic production, biochar application and agroforestry – are in theory more accessible and could be implemented at relatively low costs, given a long-term perspective.

Many of these measures are hindered by a common barrier in Georgia: unclear land tenure regulations in many areas of the country, especially in rural areas, leads to the situation where land users do not have a strong enough guarantee on their land ownership to invest in sustainable practices that pay-off over the longer-term. In particular, long-term soil quality is undervalued; several measures oriented towards sustainable soil management are overlooked, while increasingly high-input and high-disturbance practices are performed on a season-to-season basis to compensate in the immediate-term for the increasingly degraded quality of the soils that those same practices cause over time. If this barrier would be overcome, and land-users would adopt a longer-term perspective to land management, awareness and education programmes could unlock a wave of action at low cost.

Project-based interventions that looks to overcome capital-related barriers are not necessarily suitable for addressing these barriers. Voluntary climate finance could support awareness and education programmes, but the relative accessibility of such measures towards the objective of raising the ambition of national climate change targets means that such interventions are not well suited to carbon crediting mechanisms that are associated with offsetting or compliance claims, or otherwise dependent on a high guarantee of additionality.

Investments can support demonstration projects and scaling up instruments for relatively accessible emission reduction measures in the livestock sector.

The prospects for climate change mitigation in the livestock sector are limited. The emission reduction potential of current technologies and measures is marginal, and even the innovative technologies that are emerging or in research and development still do not carry the potential for very deep emission reductions. As long as there are no known technological options for far deeper emission reductions in the livestock sector, it is contentious whether any technologies for marginal emission reductions in this emissions-intensive sector can be aligned with global net-zero emission objectives. Such measures may be incompatible with those objectives, or an inefficient means of working towards them, if the limited technological options means that deep decarbonisation can only be achieved through a broader food transition that includes a shift away from livestock agriculture.

Despite these limitations, a number measures are available to achieve marginal emission reductions in the livestock sector in the short-term, at low to moderate cost levels. This includes grazing land management, manure management, feed optimisation, breeding optimisation, health and disease prevention. These relatively accessible measures have not advanced far in the Georgian context, due to lack of finance and regulatory attention.

Increased investments are needed to support demonstration projects and scaling up instruments for those measures. Voluntary climate finance could be well suited to this objective, but the relative accessibility of such measures towards the objective of raising the ambition of national climate change targets means that such interventions are not well suited to carbon crediting mechanisms that are associated with offsetting or compliance claims, or otherwise dependent on a high guarantee of additionality.

Emerging technologies for emission reductions from the livestock sector are unlikely to represent high-hanging fruit projects that are suitable for voluntary project-based finance.

New technologies for direct methane capture are emerging, which could reduce emissions from enteric fermentation by up to 53%. Although these technologies remain novel today, it is possible that relatively low marginal abatement costs could quickly increase the accessibility of the technologies once it is demonstrated. In the meantime, project-based finance is probably less suitable in the process of technological research and development since this is already being pursued by private sector finance with commercial interests.

Other options for advanced inhibition of enteric fermentation are also under research and development. Enteric fermentation could be further inhibited through anti-methanogen vaccinations, or novel feed additives. Anti-methanogen vaccinations are under development and have been used in small-scale trials in a handful of countries (WRIGHT, 2004; Zhang et al., 2015). The state of scientific knowledge on feed additives for inhibiting enteric fermentation is regularly advancing, and novel options may be expected to come to market in the future. The role of project-based finance to address further technologies for advanced inhabitation of enteric fermentation is potentially limited, especially for the Georgia context specifically. Although project finance may be a potential avenue for research initiatives, global research efforts are also currently pursued by under large-scale research grants and through private sector finance with commercial interests.

THE EXTENT TO WHICH SUCH MEASURES COULD BE HIGH-HANGING FRUIT PROJECTS IN OTHER COUNTRIES IS HIGHLY CONTEXT SPECIFIC.

The conditions for the cropland measures identified as high-hanging fruit projects in the Georgian context will be highly variable between countries. In some industrialised countries, zero-emission machinery is already emerging while in most developing countries and emerging economies these technologies are still very novel. The accessibility of genetic editing, microbiome technologies and perennial grain cropping will depend on the extent of existing research and development in the specific region since the development of solutions is very specific to local soils and crops. Some of these measures are emerging in countries where the locally-specific R&D efforts are well developed, while in other countries the state of knowledge and availability of these measures is still far more limited.

ELECTRIFIED FARM MACHINERY

The full electrification of farm machinery and equipment, including battery-powered tractors, harvesters and dryers, can reduce the direct emissions associated with energy use in agriculture.

Status

Electrified farm machinery technologies are not yet available in Georgia. The electrification of large-scale farm machinery and equipment is not yet widespread in any country, but there are prospects for these technologies to become competitive in the mid- to longer-term future.

Potential & costs

Up to 100 ktCO_2e mitigation potential in 2030: Most of the emissions from energy use in agriculture could be reduced by the electrification of farm machinery and equipment, if combined with the generation of renewable electricity.

High marginal abatement costs (> 100 USD/tCO_2e): As zero-emission vehicle technologies further develop and become cheaper to manufacture, they may eventually become a cost-competitive alternative to diesel-powered machinery in many countries. However, since the majority of farms in Georgia make use of older imported equipment, the high capital expenditure to acquire zero-emission machinery is likely to remain comparatively expensive for the foreseeable future, making this a **high-hanging fruit project** option in the Georgian context.

Unlocking action

When a market for zero-emission farming machinery becomes accessible for Georgia, finance for demonstration projects will be required to overcome high upfront capital costs.

Zero emission machinery is highly suitable for project finance. Support projects with clear boundaries can be developed for small, medium or large project budgets, and the emission reduction outcomes can be easily quantified.

PLANT AND SOIL MICROBIOME TECHNOLOGY

In recent years, a wave of new research has shed light on the potentially significant relationships between the microbiome of soils and plants and climate change mitigation and adaptation outcomes. The bacteria and fungi that make up these microbiomes determine the quality of soils and their carbon sequestration capacity. They can also influence in different ways how the soil breaks down nitrates and emits nitrous oxide. Interventions to optimise microbiomes could significantly increase carbon sequestration and reduce nitrous oxide emissions from croplands, and perhaps also from pastures. The most accessible method of microbiome engineering is the inoculation of specially created microbiome cocktails – which contain a mixture of positive bacteria and prebiotic feed – into croplands. Further emerging technologies include plant breeding approaches to manipulate microbiomes, and microbial biotechnology approaches for in situ microbiome manipulation via use of biochemical, cellular and genome-editing methods (Hu et al., 2017).

Status Microbiome cocktails for cropland inoculation have reached the global market, but remain at an early stage of development and are oriented more at the major global cash crop markets; they are not yet used in Georgia. More advanced methods of in-situ cropland microbiome modification have only recently come onto the biochemical engineering research agenda at the global level.

Potential & costs Microbiome optimisation is currently a high-hanging fruit project option in the Georgian context, although it could become more accessible in the future. Currently available agricultural inputs for microbiome optimisation would currently be expensive to bring to the Georgian market, while the impacts for climate change mitigation and crop yields on Georgian soil are unknown. It is likely that the maturity, affordability and suitability of these inputs for the Georgian context will increase significantly in the coming decade. The costs and mitigation potential biotechnological options for in-situ microbiome manipulation remain unclear, as those measures remain at an early stage of research and development.

Unlocking action Participation in global research efforts could support an increased understanding on the local suitability of solutions that emerge, and may lead more quickly to the development of more locally appropriate options. Project-based finance delivered through a climate contribution model that is not attached to carbon crediting mechanisms could be an effective means of supporting the next steps for Georgian participation in R&D programmes, locally-specific R&D, and pilot projects to test emerging locally-specific solutions.

The research and development that is likely necessary on the local level before projects can be implemented, makes this measure currently somewhat unsuitable for carbon crediting mechanisms that depend on quantifiable emission reduction outcomes The non-permanence of carbon sequestration outcomes also makes some of these projects unsuitable for offsetting claims, even once those outcomes can be quantified **(see → Section A1.2)**.

NEW PERENNIAL GRAIN CROPS

Perennial crops are those which live for multiple years without needing to be replanting after every harvesting season. Recently, new species of perennial wheat-like grains have been discovered or developed. Compared to other crops, perennial cropping leads to less carbon release and soil erosion that may otherwise be caused by tillage, seeding and other soil disturbances. Perennial crops improve soil structure, water retention and carbon sequestration.

Status

Georgia is well familiar with traditional perennial crops, with vineyards and orchards accounting for approximately 25% of cropland in 2018, but there is currently no use of new perennial grains in Georgia. New perennial grains are gaining traction at the international level as a high potential climate change mitigation measure, but are not in widespread use in any country. International research efforts are likely to significantly increase the availability of perennial cropping over the next decade.

Potential & costs

The mitigation potential could be in the order of 70 $ktCO_2e$ in 2030, assuming a switch to perennial wheat grains from annual what crops, which currently occupy approximately 50,000 hectares of Georgian cropland (Ministry of Agriculture and LTD Georgian Amelioration, 2017). This estimation assumes a similar climate change mitigation impact from other conservation agriculture measures combined; the specific climate change mitigation potential of perennial cropping is still highly uncertain and the subject of international research. The potential could be significantly higher still, if new perennial grains could also replace annual barley and maize crops.

Further international research and development is needed, before meaningful predictions can be made on the costs, which depend on market supply prices and crop yields.

The development of new perennial grains could be considered a **high-hanging fruit project** in the Georgian context, on account of the fact that there is currently no use of such crops in Georgia. Cropping with new perennial grains will possibly become a much more accessible measure once the first handful of projects have introduced these grains to the local market.

Unlocking action

Project-based finance delivered through a climate contribution model that is not attached to carbon crediting mechanisms could be an effective means of supporting the next steps for Georgian participation in R&D programmes, locally-specific R&D, and pilot projects to test emerging locally-specific solutions. The research and development that is likely necessary on the local level before projects can be implemented, makes this measure currently somewhat unsuitable for carbon crediting mechanisms that depend on quantifiable emission reduction outcomes The non-permanence of carbon sequestration outcomes also makes some of these projects unsuitable for offsetting claims, even once those outcomes can be quantified **(see → Section A1.2)**.

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