PATHWAYS TO NET-ZERO CITIES

The Role of Cities in Advancing Carbon Removal

XPRIZE CARBON REMOVAL | MUSK FOUNDATION

south pole

GLOBAL CARBON REMOVAL PARTNERSHIP

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About

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XPRIZE is the recognized global leader in designing and executing large scale competitions to solve humanity's greatest challenges. With over $500M in prizes over 30 years, our unique model has democratized crowd-sourced innovation and scientifically scalable solutions that accelerate a more equitable and abundant future. XPRIZE has Donate, learn more, and co-architect a world of abundance with us at xprize.org.

South Pole:

South Pole has been at the forefront of decarbonization since 2006. It has developed nearly 1,000 projects in over 50 countries to reduce over 200 million metric tonnes of CO_2 emissions, and to provide social benefits to communities who are particularly vulnerable to climate change. South Pole also implements comprehensive climate solutions and strategies that turn climate action into long-term opportunities for companies, governments and organizations around the world.

Global Carbon Removal Partnership:

The Global Carbon Removal Partnership (GCRP) is a multi-stakeholder global partnership led by the Global South focused on creating the enabling mechanisms to scale responsible natural and technological carbon removal solutions. It does this through engagement, policy and agenda setting, creating incentives, and connecting supply and demand.

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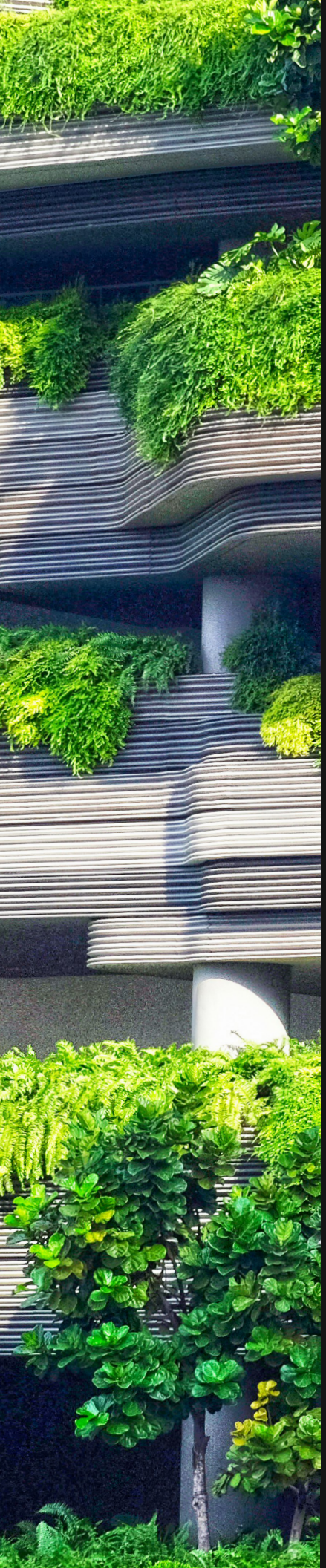
INTRODUCTION

Cities are in a unique position to drive climate action and make City CDR a reality. With urban settlements responsible for ~70% of global CO_2 emissions, cities play a crucial role in our urgent fight against climate change. Numerous cities have adopted ambitious net-zero strategies, but their carbon neutrality plans often lack precision over how their last-mile, residual emissions will be neutralized. Carbon dioxide removal (CDR) offers a way to actively mitigate emissions of carbon dioxide (CO_2) causing global warming, achieve net-zero goals and eventually reduce the absolute concentration of CO_2 in the atmosphere, while generating a myriad of co-benefits.

The 'City CDR Initiative' is an emerging capacity building program to empower cities to advance CDR. The consortium includes the C40 Cities Climate Leadership Group, Global Covenant of Mayors for Climate & Energy, XPRIZE Carbon Removal, Global Carbon Removal Partnership, and South Pole. With the City CDR Initiative, the consortium aims to build a coalition of cities to advance removals for a net positive living environment. This baselining report explores the opportunity and challenges connected to City CDR and describes the different pathways of engagement for cities. It was developed as a guide and reference for cities to understand how carbon removal can play an integral role in achieving net-zero strategies. The report was developed by XPRIZE, South Pole and the Global Carbon Removal Partnership. C40 and the Global Covenant of Mayors are supporting partners for the purpose of this report.

The authors of this report extend a call to action to city leaders, policymakers and stakeholders to prioritize and expedite CDR implementation efforts. The urgency of addressing climate change demands immediate action, and CDR presents a transformative opportunity to create more sustainable and resilient urban environments for both current and future generations. It is imperative for cities to seize this opportunity.

[1] Also known as greenhouse gas removal (GGR) or negative emissions.



THE CITY-CDR NEXUS

Carbon dioxide removal (CDR) from the atmosphere, alongside rapid and deep decarbonisation, is essential to limit the impacts of climate change and reach net-zero emissions. The Intergovernmental Panel on Climate Change (IPCC) has defined three roles for CDR. In the near term, it can accelerate global mitigation efforts; in the medium term, it can counterbalance hard-to-abate and residual emissions to reach net zero; in the long term, it can achieve net-negative emissions and neutralize historical emissions.

Because of the slow progress in reducing emissions, models estimate that removals of 1 $GtCO_2$ per year by 2030 and up to 10 $GtCO_2$ per year by 2050 will be required to limit global warming below 2°C. Achieving these scales will be a sizable challenge. While ~2 $GtCO_2$ per year is removed through conventional CDR, mostly from reforestation and afforestation, only 0.00135 $GtCO_2$ of this comes from novel CDR, which represents some of the most durable forms of CDR. An exponential scale-up of novel CDR methods is vitally important. This highlights an urgent gap that needs to be addressed. In this context, and as both major sources of and potential sinks for CO_2, cities have an important role to play in the global carbon removal efforts.

The Context

Cities present unique challenges and opportunities for CDR implementation, notably due to their high concentration of emission sources, their dense populations and complex infrastructures.

They also have unique competencies to implement CDR solutions, leveraging their agency over, amongst others, land use planning, public infrastructure and local policies. With 274 cities globally having committed to or proposed net-zero targets, cities are on a path to becoming leading players in advancing CDR deployment. By integrating CDR strategies into city planning and policy frameworks, cities can drive meaningful reductions in atmospheric CO_2 concentrations and enhance climate resilience. According to recent findings, the potential of urban CDR options, including the storage of carbon in urban vegetation, soils and buildings, and the capture of CO_2 from indoor environments is in the range of up to 1 $GtCO_2$ globally – a significant contribution to climate change mitigation efforts.

As climate change intensifies, the case for CDR interventions in and by cities becomes increasingly apparent. Cities are particularly vulnerable to the impacts of climate change, facing threats such as extreme heat, flooding and sea-level rise that pose considerable risks to infrastructure, public health and socioeconomic stability. As major contributors to global carbon emissions due to their dense populations, industrial activities and transportation networks, cities have a critical role to play in addressing climate change. It is essential to address emissions at the city level to achieve climate targets and reduce their carbon footprint. By actively removing carbon dioxide from the atmosphere, CDR offers a complementary strategy to emission reduction efforts and emerges as a crucial city climate mitigation solution. When organized in synergy with emissions reduction and climate change adaptation policies, integrating CDR consideration into city planning not only helps cities achieve net-zero emissions but also enhances their resilience to climate change.

The Opportunity

The significance of cities addressing CDR extends beyond exclusively mitigating climate change impacts. By strategically harnessing the co-benefits of CDR, cities can contribute to other urban priorities while progressing towards net-zero goals.

Environmentally, CDR solutions can improve air, soil and water quality, enhance ecosystem health, and boost biodiversity, thus promoting overall environmental sustainability and ecosystem services. Socially, investment in CDR solutions can lead to better public health outcomes, increased community resilience to climate impacts, and greater local engagement and environmental justice. Economically, CDR initiatives can stimulate growth, create green jobs and attract investment in sustainable technologies and infrastructure. Additionally, by mitigating the long-term costs of climate change impacts, CDR can yield significant cost savings for cities and taxpayers.

Cities implementing CDR projects can ensure alignment with local values, contributing to Nationally Determined Contributions (NDCs) that are more likely to gain support from local communities and be economically productive. In a world where large-scale CDR is inevitable, agency at the local level can ensure high-quality and just implementation. Beyond contributing to national and global carbon removal efforts, by leading by example and implementing ambitious CDR strategies, cities can influence national and international policies, contribute to global carbon removal efforts and inspire other cities to implement similar strategies. The collective action of cities is crucial for achieving global climate targets and transitioning to a low-carbon, resilient future.

A city can engage in CDR efforts in a number of different ways, with each pathway of engagement positioning it in a different role in relation to the carbon removal stakeholder ecosystem. While a city may assume multiple roles, the pathways it takes will depend on the local context, priorities and capacity. A city may position itself as a strategizer, creating strategic policy frameworks for CDR advancement; as a regulator, supporting CDR with local regulations; as a service provider, integrating carbon removal considerations into urban planning, infrastructure and public services; as an innovator, promoting local CDR research, development and innovation; as a funder, financing carbon removal project development; or as a convener, actively engaging the public and advocating for CDR advancement.

These pathways of engagement, and associated interventions, will help cities advance CDR by using technological, regulatory, financial and political-economy levers. By using these levers and engaging with CDR, cities have the potential to emerge as critical nodes for the development and deployment of carbon removals. The interconnectedness of urban and global climate challenges highlights the necessity for collaborative action across all levels of governance and society.

Cities are well-positioned to use **technological levers**. They can drive advancements by supporting research and development efforts, demonstrating pilot projects and building capacity. These efforts are crucial in making emerging technologies scalable and cost-effective, thereby enhancing the feasibility of CDR solutions.

Cities possess the authority to use **regulatory and policy levers** that can facilitate CDR adoption. They may introduce supportive policies, zoning restrictions and regulatory certainty surrounding CDR projects. By developing clear and consistent regulatory frameworks, offering incentives and streamlining project approval processes, cities can create an enabling environment for CDR investments. This approach fosters regulatory certainty and encourages private sector participation.

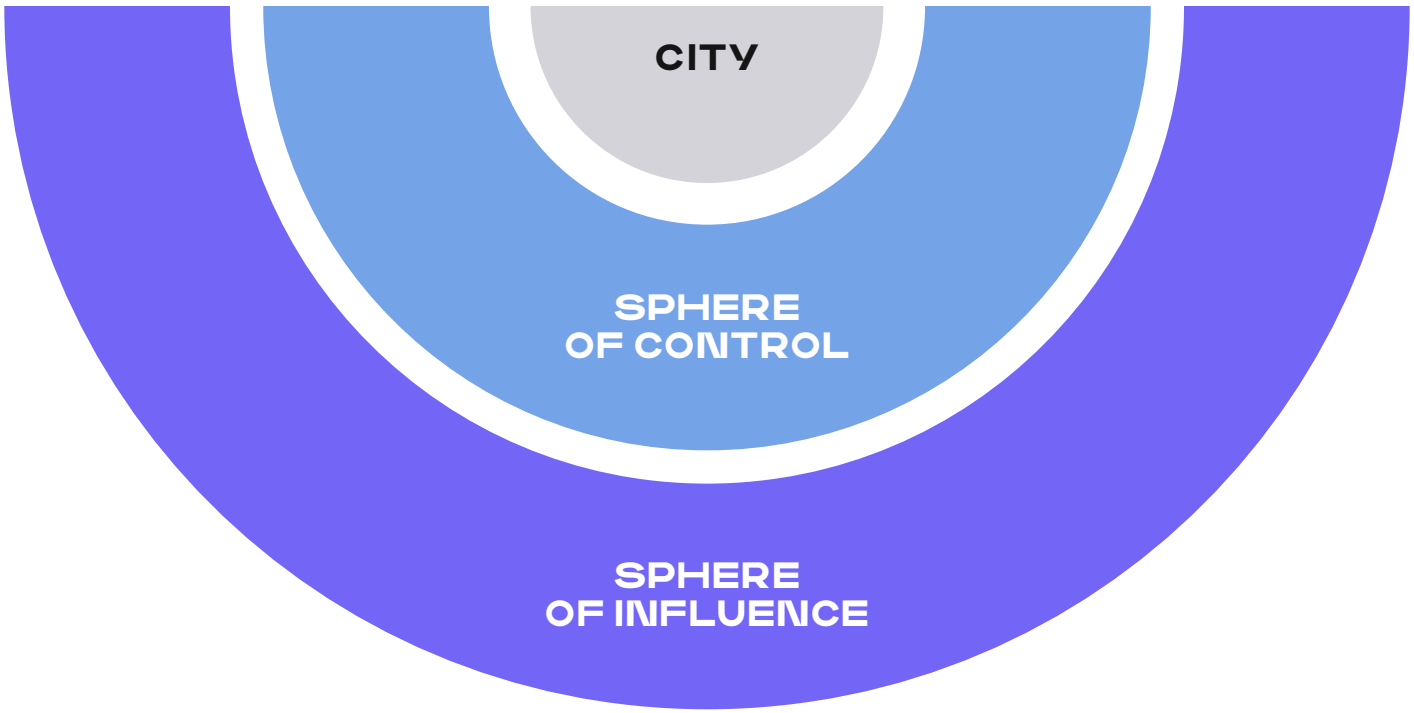
Financial levers can be effectively managed by cities through innovative financing strategies, such as making funding available for projects, addressing budgetary limitations for city governments, and making the business case. Municipalities can leverage public-private partnerships, implement carbon pricing mechanisms or issue green bonds to attract investments in CDR initiatives. By diversifying funding sources and leveraging external capital, cities can overcome budget constraints and ensure sustainable financing for long-term CDR projects.

Political-economy levers are intricately linked to community acceptance and governmental decision-making processes in cities. Engaging stakeholders, promoting public awareness and addressing equity concerns are pivotal to gaining social license and political support. Cities can align CDR goals with broader socio-economic objectives to navigate political dynamics and secure necessary resources for successful implementation. An inclusive approach fosters trust and consensus, paving the way for effective integration of CDR solutions into municipal agendas.

DEFINING CITY CDR

City CDR refers to initiatives and strategies taken by cities to actively reduce CO_2 levels in the atmosphere. These initiatives are driven by local governments, often in collaboration with various stakeholders including businesses, NGOs, research institutions, national governments, transnational municipal networks, and citizens. City CDR aims to mitigate climate change by removing CO_2 from the atmosphere, and maximizing synergies with wider city priorities, thereby contributing to overall efforts to achieve net-zero emissions or even carbon negativity, as well as other city objectives.

[2] A city could be considered carbon negative when it is removing and sequestering more CO_2 from the atmosphere than is emitted.



DEFINING CITY CDR:

Spheres of Control and Influence

With each city having its own context-specific geographic and jurisdictional particularities, City CDR initiatives can broadly be characterized on the basis of whether they fall within a city's **sphere of control** or **sphere of influence**.

This framework helps in understanding the city's level of agency and decision-making power in implementing CDR interventions, distinguishing between efforts undertaken within the city's immediate jurisdiction and those extending beyond its boundaries. It may help cities prioritize actions based on their level of influence and the potential impact they can make in each sphere.

Sphere of Control:

This sphere refers to direct municipal action and regulatory powers and covers interventions implemented or governed by the city itself. Within this sphere, City CDR interventions are directly managed or regulated by local authorities, typically falling within the city's jurisdiction and geographical boundaries. These could include the following types of interventions.

- Project Development and Ownership
- Waste and Energy Management
- Green Public Procurement
- Land-Use Planning
- Community Engagement
- Green Building Standards
- City Greening
- Financial Mechanisms
  e.g. CDR Procurement; Investments in R&D

Sphere of Influence:

This encompasses interventions that extend beyond the city's immediate jurisdiction but can be influenced or supported through the city's leadership, resources, or advocacy. City CDR interventions within this sphere leverage partnerships, collaboration, and advocacy to catalyze carbon removal activities on a larger scale, including local, regional, national, and global efforts. This sphere includes the following types of interventions.

- Project Engagement
- Regional Collaboration and Partnerships
- Advocacy for National Policies
- International Engagement
- Knowledge Sharing and Capacity Building

By distinguishing between a city's sphere of control and sphere of influence, stakeholders can better understand the range of CDR initiatives that cities can undertake and the strategies they can employ to maximize their impact on carbon removal efforts. This approach underscores the importance of collaboration, leadership and advocacy in mobilizing collective action to address climate change beyond individual city boundaries.

PATHWAYS OF ENGAGEMENT

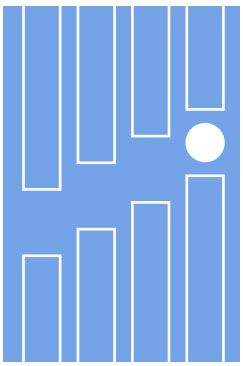
Cities have a unique position in climate multi-level governance. Their position provides them with an opportunity for policy implementation of key climate actions, while ensuring that their mitigation and adaptation efforts also cater to other social, environmental and development goals, such as promoting biodiversity and ecosystem restoration, building sustainable and resilient urban environments, providing employment opportunities and reducing inequalities. As it stands, almost all cities' net-zero strategies that we reviewed lack plans to neutralize residual emissions. Credible climate action and carbon neutrality plans and roadmaps must be underpinned by a robust carbon removal strategy, setting out what approaches will be used to eliminate the city's residual emissions. Net-zero emissions cannot be realized without carbon removals.

As advocates for climate action and hotspots for climate change impact, cities and local governments can and should drive leadership in the advancement of carbon removals.

Beyond strengthening cities' climate neutrality plans, their leadership in this space would draw greater attention to a climate change mitigation practice that complements emissions reduction, climate change adaptation and broader development interventions. Cities are well-placed to support the nascent CDR industry, support local innovation, grow nature-based solutions, and empower citizens and civil society to get engaged in local projects. With these overarching goals in mind, local governments can intervene in multiple ways to advance carbon removals, both within their spheres of control and influence.

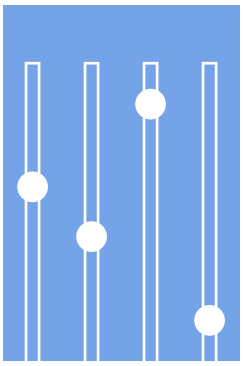
Cities can play a number of distinct roles when engaging with CDR, with each pathway of engagement addressing a different facet of CDR advancement. By engaging through these diverse pathways, cities can simultaneously address immediate local concerns and contribute to broader, systemic changes in carbon management. This multifaceted approach allows cities to leverage their unique strengths and resources, tackling carbon removal from multiple angles to generate impact in a manner that is specifically suited to their individual context.

City CDR pathways of engagement include:



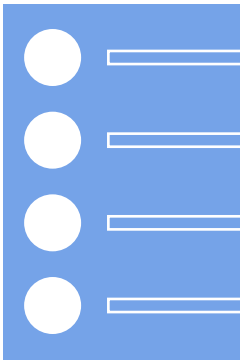
The City as Strategizer:

The city assumes a strategic responsibility for the advancement of CDR within its spheres of control and influence. The city is the central operator in the local carbon removal ecosystem, ensuring efforts undertaken by local stakeholders contribute to the realization of centrally-adopted short-, medium- and long-term objectives. The city develops clear and robust policy frameworks, roadmaps and dedicated targets for carbon removals, signaling political commitment and providing long-term visibility for investors and project developers.



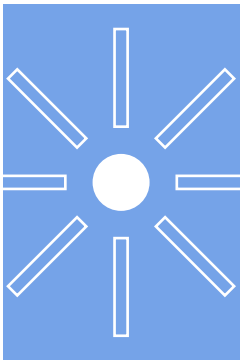
The City as Regulator:

The city assumes the role of regulator, to the extent that their specific legal competencies allow. The city creates the operating context for the local CDR sector to thrive through specific regulatory interventions. When the city takes this role, it also takes on associated responsibilities, such as conducting public consultations. The city adopts and promotes regulations that support carbon removal activities, particularly in relation to buildings and zoning rules, helping to create an enabling environment for CDR while ensuring compliance and accountability.



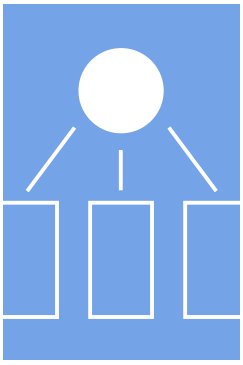
The City as Service Provider:

The city embeds CDR in its urban planning as a cross-cutting strategic issue. From an urban planning perspective, the city is reframed and organized as an area with the function to draw down and store CO_2. The city manages the built environment in a way that minimizes its impact on, or benefits the climate, by integrating carbon removal considerations into urban planning, infrastructure and public services.



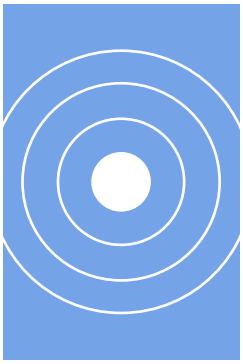
The City as Innovator:

The city assumes the responsibility to drive local and collaborative research, development and innovation efforts in the CDR ecosystem. Dedicated funding is made available and the required RD&I soft infrastructure is put in place by the city. It supports RD&I efforts, particularly in the local ecosystem, as a key area of competence of the city. Carbon removals become a distinct focus area for city programs aimed at supporting climate innovation more broadly.



The City as Funder:

The city drives demand for carbon removals by putting in place material amounts of funding and introducing, or participating in, adequate funding mechanisms. Through its efforts, the city limits financing gaps that are a barrier to scaling carbon removals. Dedicated funding opportunities at local level help pilot projects get off the ground, empower local actors to get involved or develop their own carbon removal project, and, in the longer term, reduce the costs and help scale negative emission technologies.



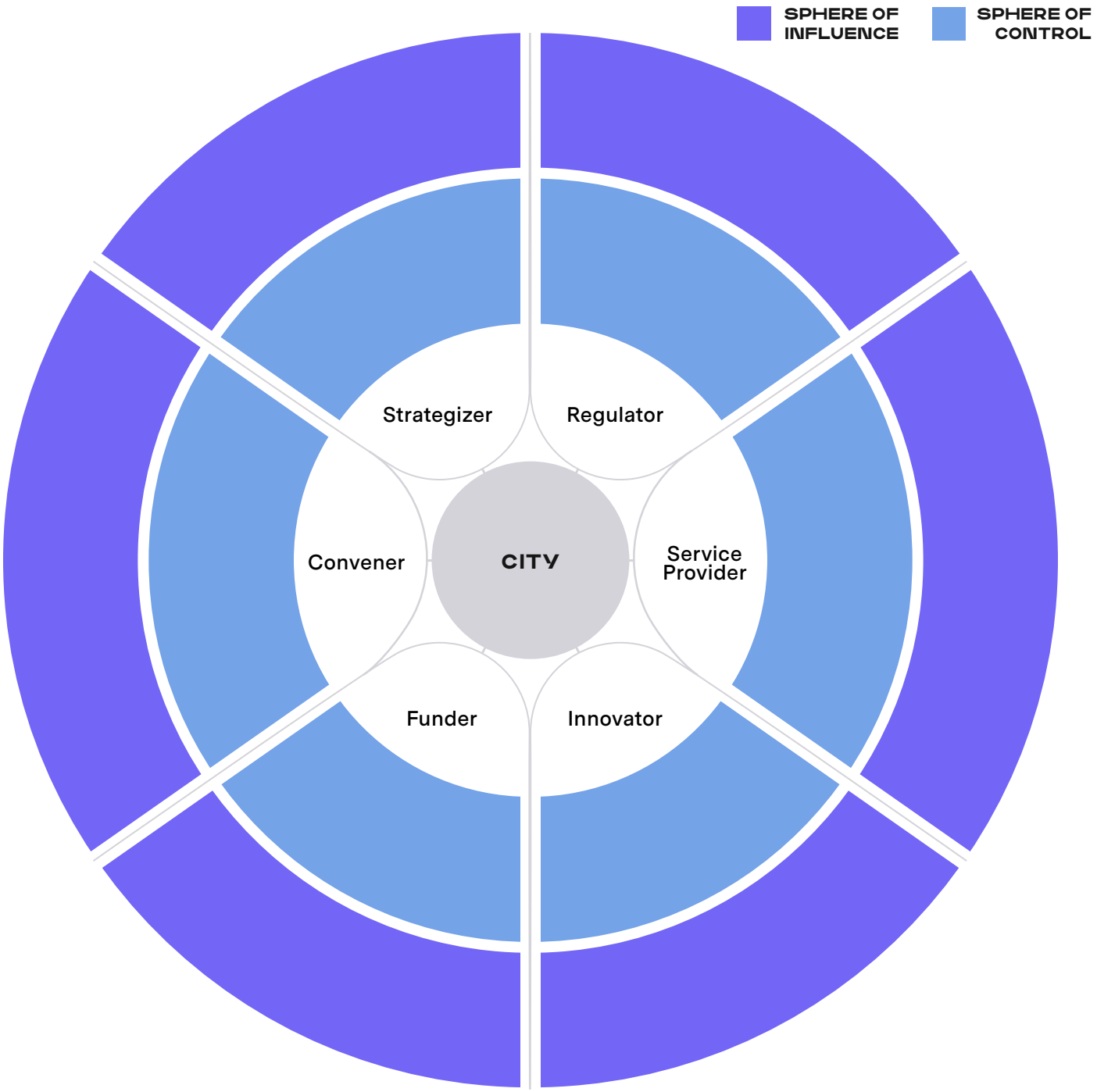
The City as Convener:

The city operates as an enabler of the local CDR ecosystem. It fosters public debate and awareness raising around the particular roles of CDR in city (climate) action plans. Decision-making processes involve direct citizen engagement and various mechanisms are implemented to consult citizens on significant decisions that affect their neighborhoods or cities, which can also be leveraged to enrich the public debate on carbon removals. The city leverages its influence to become an advocate for carbon removals initiatives, by showcasing successful projects and strategies.

PATHWAYS OF ENGAGEMENT:

City Action Tools to Incentivize Carbon Removals

A set of policy tools and city actions can be developed for each pathway of engagement — the city as strategizer, regulator, service provider, innovator, funder or convener. In both their sphere of control and sphere of influence, cities can employ these tools to advance carbon removals, demonstrating leadership and catalyzing action at the local, regional, and global levels. The below section provides indicative examples of such policy interventions.



PATHWAYS OF ENGAGEMENT

SPHERE OF CONTROL	SPHERE OF INFLUENCE
The City as Strategizer	
• Develop roadmaps, strategies and targets dedicated to carbon removals	• Develop roadmaps and strategies for cross-border CDR projects and initiatives
The City as Regulator	
• Facilitate permitting processes • Update building codes and zoning regulations	• Align regulation with neighboring municipalities and beyond
The City as Service Provider	
• Integrate carbon removal considerations into urban planning • Design buildings as carbon sinks • Explore the integration of carbon removal into public services provided by cities	• Engage with other cities and stakeholders on integrating CDR in urban infrastructure and planning
The City as Innovator	
• Design public procurement programs for 'first-of-a-kind' carbon removals • Foster local innovation hubs	• Establish partnerships with cities, academia, research and other organizations to promote innovation
The City as Funder	
• Design dedicated funding opportunities for carbon removals	• Pool CDR funding efforts of multiple cities
The City as Convener	
• Advocate for carbon removals and develop public information and awareness raising campaigns • Make use of participatory governance mechanisms to enhance dialogue on carbon removals	• Advocate for carbon removals at the national and international level • Facilitate cross-border partnerships between local businesses, research institutions and an other stakeholders to promote innovative carbon removal projects

The City as Strategizer

· Develop roadmaps, strategies and targets dedicated to carbon removals

Dedicated targets for carbon removals with specific time horizons are one of the most powerful policy tools to support the scaling of these solutions. As for other decarbonization technologies, such as renewable energy, dedicated targets support the implementation of these solutions by signaling the commitment of a particular jurisdiction and providing long-term visibility to investors and to other stakeholders that need to be mobilized in order to meet the targets.

In the case of carbon removals, calls from climate experts to better reflect the different roles of emission reductions and removals are starting to bear fruit in certain jurisdictions. For example, in its recommendation regarding the revised EU 2040 climate target, the European Commission included specific language on carbon removals, highlighting their role both in meeting climate neutrality and generating negative emissions post-2050. Having dedicated (supra-) national carbon removal targets in place will further strengthen cities' agency as actors of change in this sphere of climate action.

At the city level, targets and roadmaps have already emerged as a key tool guiding city climate action, with numerous of the world's major cities having science-based carbon neutrality or net-zero targets in place. However, while many mention and estimate the amount of residual emissions, few have set dedicated targets for how to balance them out. Establishing a roadmap to addressing residual emissions, which outlines the context-appropriate carbon removal methods to be used, is an essential step in a city's journey to supporting carbon removals, whether they would be developed within the city boundaries or purchased as carbon removal credits. This could also be in the form of carbon budgeting and sector-specific strategies

IN PRACTICE: HaliFACT, the Climate Action of the City of Halifax

HaliFACT, the Climate Action Plan of the city of Halifax, Canada, explicitly mentions "negative emissions actions", such as increasing tree canopy, restoring ecosystems and injecting carbon dioxide into concrete, as a pillar to addressing its residual emissions, estimated at 5% of emissions by 2050.

The explicit mention of the different kinds of removal approaches that are deemed necessary for the achievement of the Halifax' climate objectives sends an important policy signal. More cities could follow this example to provide additional clarity.

A further step would involve including more details regarding the sources of these projects, the timeline for deployment and the quantities of CO_2 removed.

- **Develop roadmaps and strategies for cross-border CDR projects**

Cities can form alliances with regional governments to develop a unified strategy for CDR, ensuring consistency, leveraging shared resources and creating a larger impact. This can facilitate coordinated action on large-scale projects, influencing regional policies and attracting investment. At the international scale, cities can join global networks of cities dedicated to addressing climate change and advancing CDR, enabling best practice and knowledge sharing.

PATHWAYS OF ENGAGEMENT:
The City as Regulator

- **Facilitate permitting processes**

It has been the case for renewable energy projects, and it is even more so for carbon capture and storage and technical carbon removal projects: lengthy permitting processes are a major hurdle for project developers. These projects face several significant hurdles - from lack of economic incentives, difficulties to access finance. Facilitating the obtaining of permits can help build a stronger case for investments in these projects, and cities.

IN PRACTICE: Permitting Requirements for Bio-CCS in Amsterdam

Interviews with companies in the Amsterdam Metropolitan Area and the North Sea Canal Area highlighted lengthy processes for permitting, as well as 'end-of-waste' status as a key regulatory barrier hindering the development and deployment of bio-CCS. In order to capture biogenic CO_2 from an industrial process for CDR purposes, the emission must be given the end-of-waste status. Companies are issued permits based on their specific activities; to expand activities to CO_2 capture, additional permits are required, the process for which can take up to a year. Furthermore, these permits may have associated caps or maximum ceilings on CO_2 volumes. Regional authorities have the right to make rulings on decisions to provide permits.

- **Update building codes and zoning regulations**

Building codes play a crucial role in promoting sustainable practices at the municipal level. Local building codes often include requirements regarding energy efficiency, water conservation, waste management, green materials, and guidelines for environmentally responsible design, construction, and operation of buildings. This practice pushes architects, builders, developers, and property owners to incorporate sustainability into building design and construction.

Building codes can also be a powerful tool to support carbon removal, by including requirements or incentives regarding the use of building materials that store carbon. Innovative start-ups, as well as

established players in the construction industry, are developing products that are derived from CO_2 captured from industrial processes or directly from the atmosphere. By updating building codes, cities can mandate the use of these materials in new constructions and renovations, progressively increasing the mandated percentage over the years.

IN PRACTICE: City of New York Limits Embodied Carbon from Material use of Concrete

New York, in the US, introduced a Low Embodied Carbon Concrete Leadership Act (LECCLA). This gave the city a mandate to develop limitations on embodied carbon in construction materials. The recently adopted Buy Clean Concrete guidelines stipulate that, as of 2025, concrete producers in the state of New York will need to submit environmental product declarations (EPDs) for concrete mixes used in public projects valued over $1 million and using 50 or more yards of concrete. It also applies to Department of Transportation (DOT) projects at over $3 million and using 200 or more yards of concrete.

IN PRACTICE: City of Basel legal requirements for green spaces on new buildings

Basel, in Switzerland, has supported a wide uptake in green roofs. The city first incentivized green roofs through a combination of financial regulation and building regulations, targeting businesses and residents. Laws were then enacted to make green spaces a legal requirement on new buildings. More than 1 million square meter of of green roofs have been constructed.

This new requirement adds patches of green space which promote biodiversity, defuse humidity and help to cool buildings off quicker during the summer months. Green spaces also have the capacity to remove carbon, making them a key feature in the design or renovation of buildings as carbon sinks.

- **Align regulation with neighboring municipalities**

Collaboration with other cities to develop and adopt shared standards for CDR technologies and practices enables standardization can reduce barriers to implementation, as well as create a larger market for CDR, contributing to driving down costs and improving efficiency. Aligning regulation can be considered together with the development of cross-border policy objectives and collaboration around project development and funding, combining the often scarce city resources in coordinated campaigns to maximize the impact of CDR interventions. Cities can also introduce cross-border regulatory sandboxes. Policy harmonization through work with regional and national governments ensures streamlined CDR implementation. This can eliminate regulatory conflicts, facilitate larger-scale projects where different parts of the project value chain are situated across the jurisdictional boundaries of multiple cities and create a more effective regional or national approach to CDR.

The City as Service Provider

· Integrating carbon removal considerations into urban planning

Rapid urban development has often been done to the detriment of nature, which in turn has generated negative consequences on the environment, biodiversity and human well-being. Shifting to a nature-based infrastructure model in cities, which would instead harness nature to provide infrastructure services, would provide a number of benefits for city residents. Nature-based infrastructure includes restoring natural ecosystems, such as forests, mangroves, wetlands and grasslands, or intervening in the built infrastructure to include structures such as rain gardens or green roofs.

When it comes to nature-based urban infrastructure, sequestering carbon may even be seen as a marginal benefit compared to all the other more tangible benefits that derive from it, such as reduced air pollution, reduced heat-island effect and improved well-being for residents. Nevertheless, highlighting a carbon removal dimension into urban planning would reinforce the case for more nature-based solutions in urban areas. When developing a carbon removal strategy to suit their unique needs and priorities, cities can take a 'co-benefits' first approach.

A further step could involve including technical carbon removal features into urban infrastructure. An interesting concept is the distributed network of Direct Air Capture (DAC) units, imagined by Carbon180, a US-based NGO. Their concept involves the integration of DAC into community recreational spaces, housing, and privately-owned public spaces such as parking lots. Cities could encourage uptake in the form of incentives for green buildings that incorporate carbon capture and storage technologies. With its Local Law 97, New York City has encouraged the uptake of decentralized carbon capture equipment at scale of individual buildings.

IN PRACTICE: Urban forests developed by Navi Mumbai

The municipality of Navi Mumbai, India, together with a local NGO, converted a space used as a dump yard in Nisarg Udya into an urban forest in an area of 1.2 hectares. The project was completed in 2021.

A dense urban forest was created following a survey from neighborhood areas which had the mission to identify native species. Over 60 native species were identified and divided into four categories - tree, sub-tree, canopy, and shrub - to create a multi-layered evergreen forest.

Beyond the capacities of the project to sequester carbon, the project brings a wealth of benefits for the local community: habitat and biodiversity restoration, reduced air pollution, recreational opportunities for residents, and strengthened community ties through volunteering.

This project was funded with private finance, through the corporate responsibility program of a major international company.

IN PRACTICE: Green corridors in Medellin

To fight the increasingly severe urban heat island effect, the city of Medellin, Colombia, initiated in 2016 a project to build 30 green corridors, planting 8,800 trees and palms, covering 65 hectares.

This project brought a wealth of ecosystem services to the city: it is reducing the average city temperature by 2°C, improving air quality by capturing particulate matter, increasing urban biodiversity, in addition to enabling the sequestration of CO_2 by the newly planted trees.

The development of the green corridors also had a significant citizen engagement dimension. It was enabled by democratic vote through the Participatory Budget of the city, and it was also brought to fruition with the help of 75 citizens from disadvantaged backgrounds, who were trained in urban gardening and tree planting techniques.

· Applying principles of regenerative design to buildings and other types of urban infrastructure

With urban climate action considerations in mind, the concept of regenerative design seeks to create products and systems that go beyond ceasing to contribute to the climate crisis but actively working towards reversing it. With the imperative of reaching carbon neutrality and heading towards net-negative post-2050, the paradigm must shift to thinking of and designing the built environment and other types of urban infrastructure as carbon sinks, which actively sequester or offset more carbon dioxide than is emitted during their construction, operation and eventual demolition.

As the global urban population continues to grow, so will the built environment. It is paramount that this accelerating phase of urbanization is in line with climate neutrality goals.

Design elements that make a building carbon negative include integrating green roofs, vertical gardens, or landscaping with native plants to enhance biodiversity, improve air quality, and sequester carbon, and use construction materials that store emissions captured from such as direct air capture. A target for carbon negative buildings among the new or refurbished buildings, particularly the ones destined for public use such as libraries, schools, administrative buildings, can serve as testament to the city's commitment to sustainable development and climate action.

· Integrate carbon removal into public services provided by cities

Energy and waste management are some of the most important public services provided by cities. Integrating carbon removal into these services can significantly contribute to achieving climate targets. Waste-to-energy plants, for instance, are recognised for converting non-recyclable waste into clean energy, reducing landfill waste. By capturing and storing the biogenic emissions they produce, these plants can also provide durable carbon removals. This method generates traceable, long-term carbon storage solutions, while also producing clean energy and disposing of non-recyclable waste.

Municipally-owned waste-to-energy infrastructure is particularly suited for integrating carbon capture and storage (CCS) installations. Planning for these installations can help cities generate negative emissions at scale. However, scaling this technology requires clear political leadership due to high costs and the complexities of transporting captured CO_2 to storage sites. Early adopters can achieve high impact by piloting projects, sharing lessons learned, and setting the stage for cost reductions. Cities are well-positioned to lead in this area, incorporating carbon removal into key public services. Trondheim, Norway is an example of a city exploring how CCS from biogenic carbon emissions can contribute to its 2030 climate neutrality target. This integration of CCS into city-level climate governance serves as a model for other cities aiming to incorporate carbon removal into public services, thereby advancing their climate action agendas.

Beyond waste-to-energy plants, cities can retrofit existing infrastructure to include CDR technologies. For example, biochar can be used in landscaping to sequester carbon. Urban forestry programs can also be enhanced to capture more carbon, while improving air quality and urban green spaces.

IN PRACTICE: Negative emissions through BECCS in Stockholm's 2030 Climate Neutrality Commitments

In its 2030 Climate Neutrality Action Plan, the City of Stockholm explicitly refers to the use of BECCS to counter the residual 700,000 tonnes of CO_2e, and go beyond net-zero. The timeline of the city of Stockholm is highly ambitious, aiming for carbon neutrality by 2030.

By committing publicly to this target through its climate action plan, providing an estimate of the residual emissions to be counterbalanced by a specific technology, the city of Stockholm is providing long-term visibility to the industry and assures them of its commitment to this technology for meeting the city's climate goals.

- **Engage with cities and other stakeholders on integrating CDR in urban infrastructure and planning**

Collaboration on inter-city infrastructure projects can create more significant environmental benefits than isolated efforts, as well as enhance regional connectivity and provide economies of scale. This can cover more technology-based projects, such as shared waste-to-energy plants, as well as nature-based projects, such as the establishment of green corridors.

Engagement can also be in the form of regional workshops, with urban planners from multiple cities sharing knowledge, strategies and best practices for integrating CDR into urban planning, leading to more effective and coordinated regional planning.

· Public procurement programs for 'first-of-a-kind' carbon removals

Public procurement is a powerful tool for promoting innovation, and it is also recognized for its role in fostering more sustainable development, through a dedicated target within SDG12. Public procurement offers a significant leverage in driving demand for environmentally friendly goods and services, thereby encouraging market transformation towards sustainability.

By sourcing construction materials with a low carbon footprint, which can include products derived from carbon removed from the atmosphere, such as cement and aggregates, cities can directly contribute to mitigating climate change while simultaneously supporting local economies and fostering innovation in sustainable practices. Local public procurement can therefore be particularly suited to promote carbon removals that involve materials that are integral to infrastructure projects and municipal operations.

IN PRACTICE: The City of Helsinki's Roadmap for the Circular and Sharing Economy

The Roadmap, which is one of the 147 actions included in the Carbon-neutral Helsinki 2035 Action Plan, recognizes the importance of the circular and sharing economy in enabling a carbon neutral future. The focus areas of the roadmap are construction, procurements, green waste and the sharing economy. Through time specific goals, such as the inclusion of circular economy criteria for all public procurements by 2050, Helsinki is showing a clear commitment for transitioning key sectors such as construction to carbon neutrality, and for using public procurement as an enabler. While construction materials derived from captured CO_2 are not explicitly mentioned, the goals in the roadmap can in principle incentivise the use and procurement of such materials as long as they are cost competitive with other materials based on circular economy principles.

· Foster local innovation hubs

Fostering local innovation hubs is crucial for advancing the carbon removal industry and accelerating the development and deployment of effective solutions. Cities can play a vital role in supporting these hubs by providing an ecosystem conducive to innovation and entrepreneurship.

Innovation is at the heart of the carbon removal industry, and successful start-ups often kick-off in cities, where they have access to talent, research facilities, and proximity to investors. By nurturing a supportive environment for start-ups and small businesses focused on carbon removal technologies, cities can attract and retain top talent, facilitate collaboration between researchers and industry experts, and provide access to resources such as funding, mentorship, and specialized infrastructure.

Cities can support innovation in carbon removal through various initiatives, including establishing incubators, accelerators and living labs tailored to the needs of carbon removal startups, fostering partnerships between academic institutions, research centers, and private sector entities, and providing funding and incentives for research and development in carbon removal technologies. Additionally, cities can promote knowledge sharing and collaboration through networking events, workshops, and conferences focused on carbon removal, creating opportunities for innovators to exchange ideas, showcase their technologies, and form partnerships.

- **Establish partnerships with cities, academia, research and other organizations to promote innovation**

Partnerships can be in the form of research consortia with universities, research institutes and private sector partners to advance CDR technologies and methodologies, enabling the pooling of intellectual and financial resources. Cities can also encourage and facilitate joint ventures between local businesses and firms specializing in CDR technologies, to promote technology transfer, attract investment and build local capacity.

IN PRACTICE: Climeworks, a carbon removal success story born in the city of Zurich

An example of a successful startup that received initial funding through an incubator financed by the city is Climeworks. The Direct Air Capture pioneer received initial funding from Zurich's Climate-KIC Accelerator program, which is supported by the city of Zurich and the European Institute of Innovation and Technology (EIT).

Climeworks is now a leading player in the carbon removal industry, with several commercial projects deployed worldwide and partnerships with governments, corporations, and research institutions.

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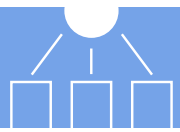
The City as Funder



· Design dedicated funding opportunities for carbon removals

Cities can explore the option of dedicated funds for carbon removals, especially for smaller scale, collaborative solutions, which can take place with community participation. Although cities may not always have the financial bandwidth within their existing budgets to set up funding mechanisms, opportunities such as municipal bonds or municipal carbon taxes can help crowd in the necessary capital needed to fund projects where a clear public benefit is identified.

One approach to designing dedicated funding opportunities for carbon removals is to establish grant programs specifically targeted at supporting local initiatives. These grants can be allocated to projects that demonstrate innovation, scalability, and effectiveness, with a particular emphasis on solutions that engage and benefit local communities. By providing financial assistance to grassroots initiatives and community-led projects, cities can empower residents to actively participate in carbon removal efforts and contribute to climate action at the local level.

Cities can also explore alternative financing mechanisms such as revolving funds, impact investment funds, and public-private partnerships. Revolving funds, for example, can provide low-interest loans or investments to carbon removal projects, with returns reinvested into additional projects over time. Impact investment funds, on the other hand, attract private capital from investors interested in both financial returns and positive environmental outcomes, thereby unlocking new sources of funding for carbon removal initiatives.

IN PRACTICE: The Urban Forest Fund by the City of Melbourne

The City of Melbourne, Australia, established a fund which provides financial support for a variety of new greening projects in the city, ranging from tree planting, green roofs, biodiversity projects and vertical greening.

The city is matching on a dollar-for-dollar basis projects for new green spaces on private properties. Residents also have the possibility to contribute to the fund.

Since the Urban Forest Fund was established, over $1.7 million in funding were offered to greening projects throughout four rounds of grants.

IN PRACTICE: The Climate Action tax by the City of Halifax

Collected as a percentage of the property tax, the climate action tax is used to fund initiatives outlined in the municipality's long-term climate action plan.

Cities choosing to implement a similar tax can then allocate parts of the collected funds to different local carbon removal projects, companies or research initiatives.

IN PRACTICE: City of Zurich purchasing program for negative emissions technologies

As part of its plan to reach climate neutrality by 2040, the City of Zurich plans to balance its residual emissions with negative emissions technologies that durably store the CO_2 of biogenic origin.

The city council is requesting new one-off expenditure of 35,474,000 francs and new recurring expenditure from 2028 for projects that capture and store the CO_2 particularly from wastewater treatment plants operated by the municipality.

- **Pool CDR funding efforts of multiple cities**

Pooling funding efforts could take the form of regional investment funds dedicated to CDR projects, increasing the funding available for CDR initiatives, enabling more significant and impactful projects and minimizing risk by reducing individual financial burdens.

IN PRACTICE: The 4 Corners Carbon Coalition

The 4 Corners Carbon Coalition exemplifies a collaborative municipal approach to CDR, emphasizing the critical role of local governments in combating climate change. A group of local governments – Boulder County, Flagstaff, Salt Lake City, Santa Fe, Bernalillo County and Alburquerque – leverage their unique knowledge and capacities to form partnerships and fund innovative CDR projects. By pooling resources and committing to joint funding efforts, these cities drive the implementation of impactful carbon removal solutions and enhance the scalability and replication of successful projects through "multiplier" campaigns. This cooperative framework ensures that local governments are at the forefront of establishing and advancing effective, community-centered strategies for atmospheric restoration.

· Advocate for carbon removals, develop public information and awareness raising campaigns

Carbon removals, especially technological approaches, are often overlooked or misunderstood in debates about climate action. Unlike more familiar strategies like renewable energy or energy efficiency, carbon removal technologies may not benefit the same level of awareness or recognition. Therefore, significant efforts are required to raise awareness about the importance and specific roles of carbon removal in combating climate change.

Public information and awareness campaigns play a crucial role in addressing this gap in understanding. These campaigns can educate individuals and communities about the significance of carbon removal and its potential to mitigate climate change, helping imprint the necessity of carbon removal into the collective mindset, emphasizing its role alongside other climate solutions. It is important that the climate benefits are highlighted alongside evidence of CDR projects bringing down the costs of other policies or generating fresh revenue streams for the municipality that can be dedicated to meeting other city priorities that benefit citizens directly.

These campaigns can go beyond informing and engaging local residents, and try to serve as catalysts for broader action. By showcasing successful initiatives and highlighting the benefits of carbon removal, cities can encourage other cities to adopt similar carbon removal strategies, and contribute to amplifying the overall impact of these efforts.

· Make use of participatory governance mechanisms to enhance dialogue on carbon removals

By making use of participatory governance mechanisms, such as citizen climate assemblies, public consultations, advisory committees and task forces, cities can enrich the debate over what climate solutions are needed, which ones should be prioritized and why. Carbon removal projects in cities can have a very tangible impact on the day-to-day life of residents, or they might need their active participation and buy-in to come to fruition. This is why engaging residents in the debate and decision-making processes around carbon removals can be a critical element in the success of an urban strategy for removing carbon. Furthermore, cities must consider the role of engaging with indigenous communities through these participatory mechanisms. Ensuring all voices are included not only promotes inclusivity and respect but also enhances the robustness and cultural relevance of urban carbon removal strategies.

· Advocate for carbon removals at the provincial, state, national, and international levels

By actively participating in climate forums and policy discussions, cities can influence broader legislative frameworks that prioritize and incentivize carbon removal initiatives. This includes lobbying for supportive policies, subsidies and grants that reduce financial barriers and encourage the adoption of CDR technologies. Through collaboration with other cities and regions, cities can build a united front

to strengthen the global push for comprehensive CDR strategies. Such advocacy efforts not only help secure funding and support for local carbon removal projects but also contribute to the establishment of standardized regulations and guidelines. By showcasing successful initiatives and sharing best practices, cities can then inspire similar efforts elsewhere, amplifying the impact of local innovations on a global scale.

IN PRACTICE: The Best Practices Playbook and a Local Strategies Playbook developed by Boulder Country

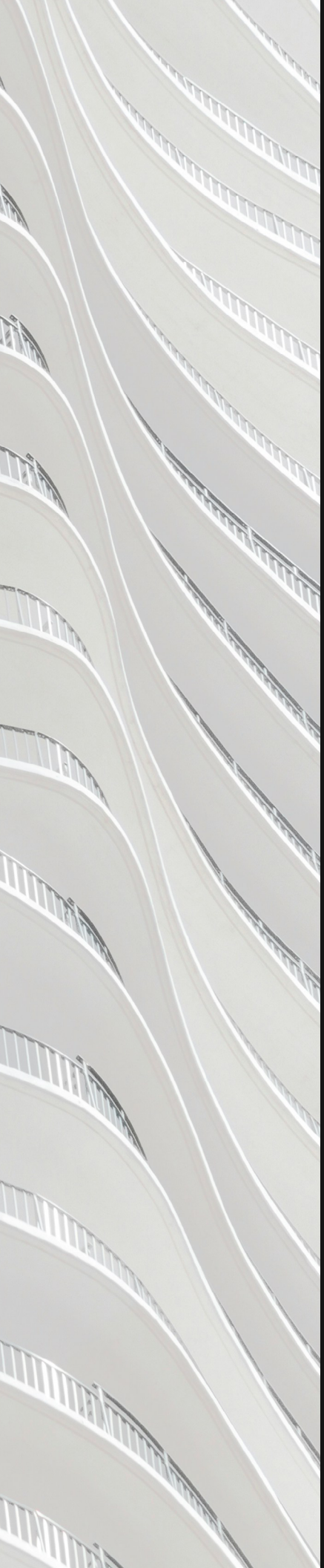
Drawing on its own experience on developing local carbon removal projects, Boulder's County, in Colorado, USA published a best practices playbook that provides guidance for governments, decision-makers, and facilitators on incorporating carbon dioxide removal into local climate action plans. This is a great example of striving for impact beyond the local realm, by disseminating the lessons learned throughout the design and implementation of a carbon removal strategy by a local government.

In addition to the Best Practices playbook, Carbon Direct, Boulder County, and the 4 Corners Carbon Coalition have also released 'Carbon Removal Strategies for Local Communities', which explores the ways local governments can leverage carbon removal to reduce climate impacts and improve community resilience.

- **Facilitate partnerships between local businesses, research institutions and other stakeholders to promote innovative carbon removal projects**

The city plays a key role in fostering collaboration among local businesses, research institutions, and other stakeholders, such as non-profit organizations, to drive innovative carbon removal projects. By creating a platform for these diverse stakeholders to connect and work together, the city can stimulate the development and implementation of carbon removal technologies and practices. These partnerships can leverage the unique strengths of each stakeholder: businesses provide funding and practical applications, research institutions offer scientific and technical expertise, and non-profit organizations ensure community engagement and advocacy.

Facilitating these partnerships could involve organizing forums, workshops and networking events to bring potential collaborators together, as well as providing support for joint project proposals and funding applications. This collaborative approach can accelerate the advancement of carbon removal technologies and ensures that projects are community-focused and aligned with broader sustainability goals.



PERSPECTIVES FROM CARBON REMOVAL DEVELOPERS

The pathways of engagements and associated city action tools explored earlier in this report serve to advance carbon removals, and support the emerging carbon removal ecosystem. While City CDR interventions should be tailored to a city's priorities and resources, they should also serve to advance the needs and expectations of the carbon removal project developers working to advance these innovative solutions.

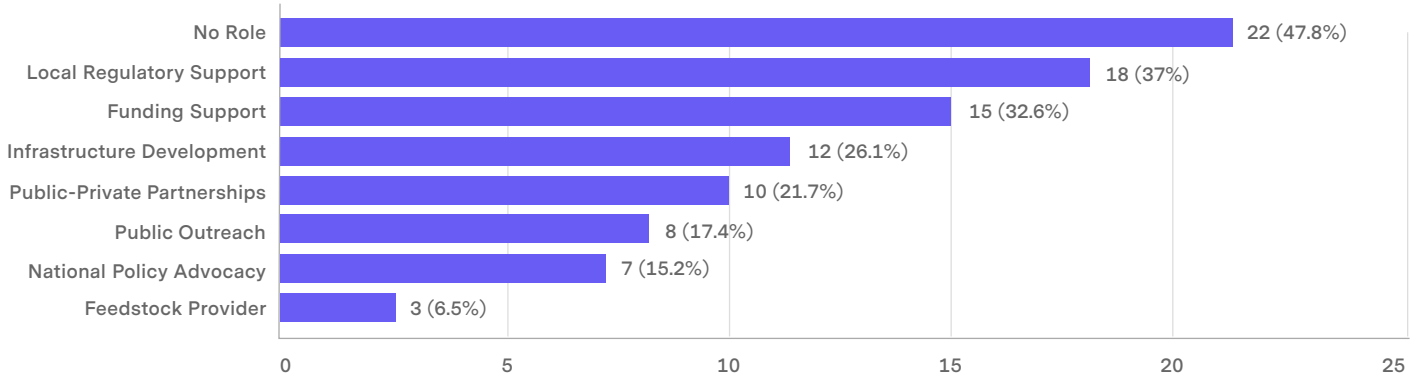
Analyzing the needs and expectations of CDR companies provides valuable insights into the role of and opportunity for city support. Understanding the barriers and levers to carbon removal deployment will help cities generate maximum impact through their interventions. To this effect, a survey was circulated among the XPRIZE Carbon Removal Top 100 Teams, a list of the leading carbon removal companies announced in May 2024.

The questions put forward in the survey provide an initial introduction into the existing and envisaged city interventions by CDR project developers. Although further research is needed to gather more granular data, the results of this survey show a clear trend; project developers want cities to take a more active role in supporting the CDR ecosystem and advancing project deployment.

Survey Results

HOW ARE CITIES INVOLVED IN ADVANCING YOUR SOLUTION TODAY?

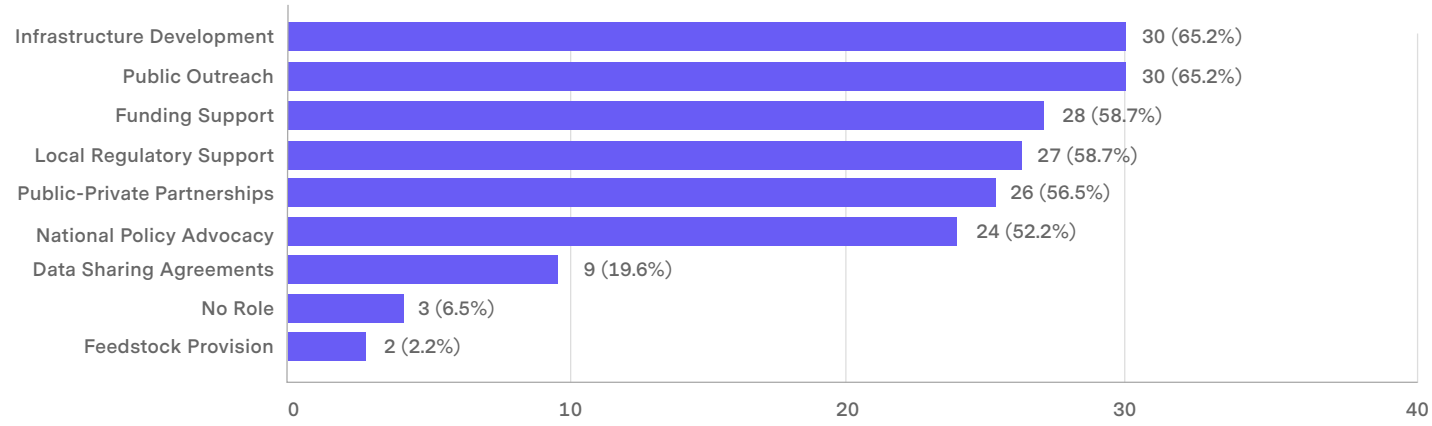
Check all that apply. (46 Responses)



Just over half of the respondents have indicated that they already receive local regulatory, funding and infrastructure development municipal support, suggesting there is already motivation to promote innovation at a local level. However, in the other 47% of cases, cities have no role in advancing the innovative solutions of the Top 100 cohort.

WHAT ROLE DO YOU ENVISION FOR CITIES IN ADVANCING YOUR SOLUTION IN THE FUTURE?

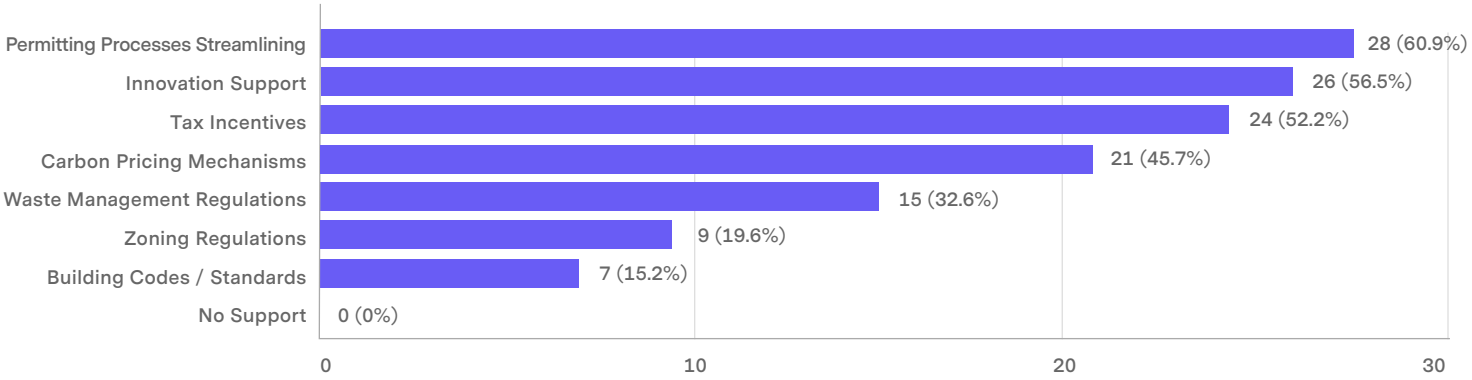
Check all that apply. (46 Responses)



Conversely, when prompted about what role carbon removal developers envision for cities in the future, nearly all foresee a role for cities in advancing their solution. A number of potential roles were put forward, including in infrastructure development, public-private partnerships, funding support and local regulatory support. City engagement in public outreach and national policy advocacy were also very popular.

WHAT POLICY OR REGULATORY SUPPORT COULD CITIES PROVIDE TO HELP ADVANCE YOUR SOLUTION?

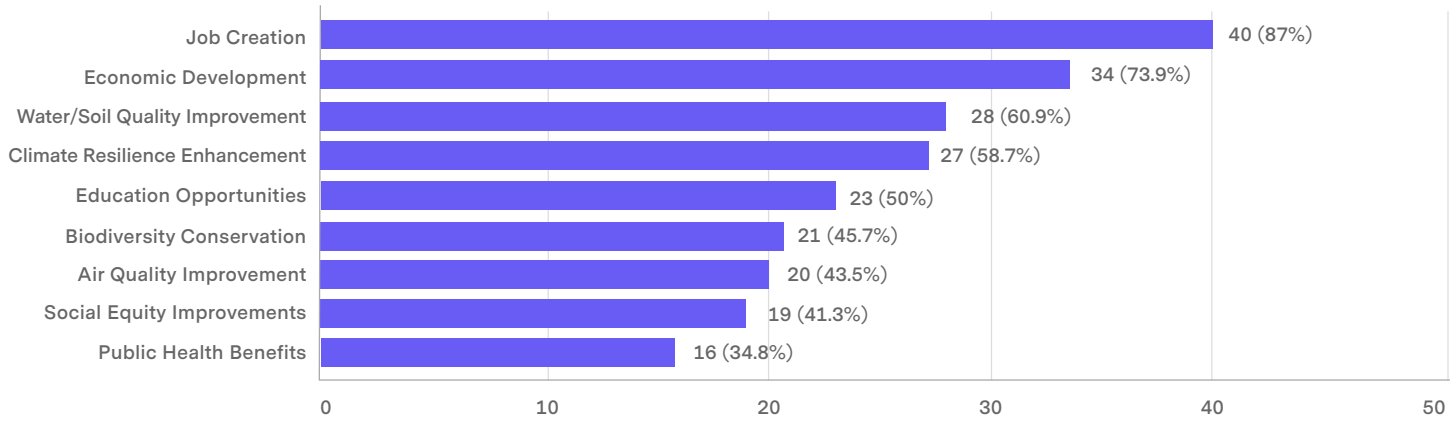
Select top three most relevant interventions. (46 Responses)



In particular, the surveyed Teams highlighted the streamlining of permitting processes, provision of innovation funding and use of tax incentives as the most relevant specific policy tools to support carbon removal development. This underscores the challenges carbon removal developers face in the early stages of operation. The establishment of carbon pricing mechanisms, waste management regulations and zoning regulations are also notable relevant solutions highlighted in the survey results.

WHAT CO-BENEFITS COULD YOUR SOLUTION OFFER TO CITIES?

Check all that apply. (46 Responses)



Cities could effectively leverage CDR start-ups to advance City CDR and achieve meaningful climate change mitigation. With all respondents identifying at least two city co-benefits to their solutions for cities, there is a clear opportunity to generate impact beyond carbon mitigation. The most common co-benefits are job creation and economic development. Over half the respondents also indicate that their solution contributes to enhancing climate resilience and water or soil quality and provides education opportunities.

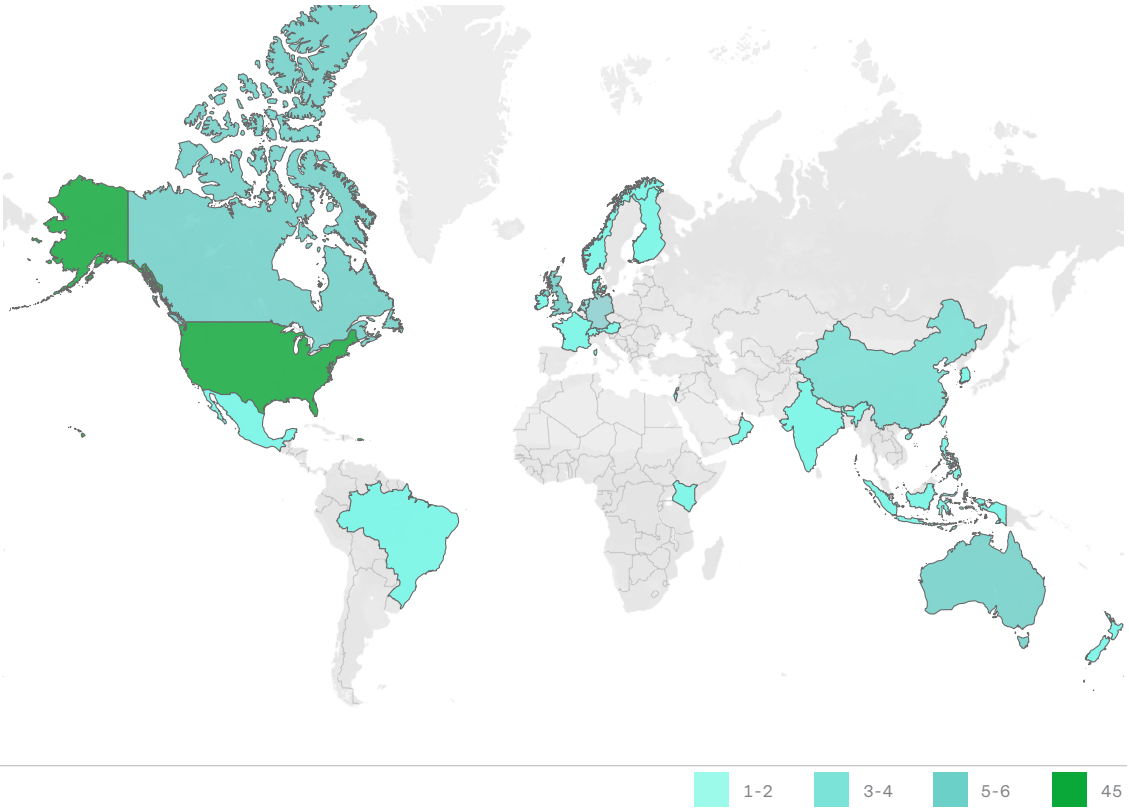
Background on XPRIZE Carbon Removal

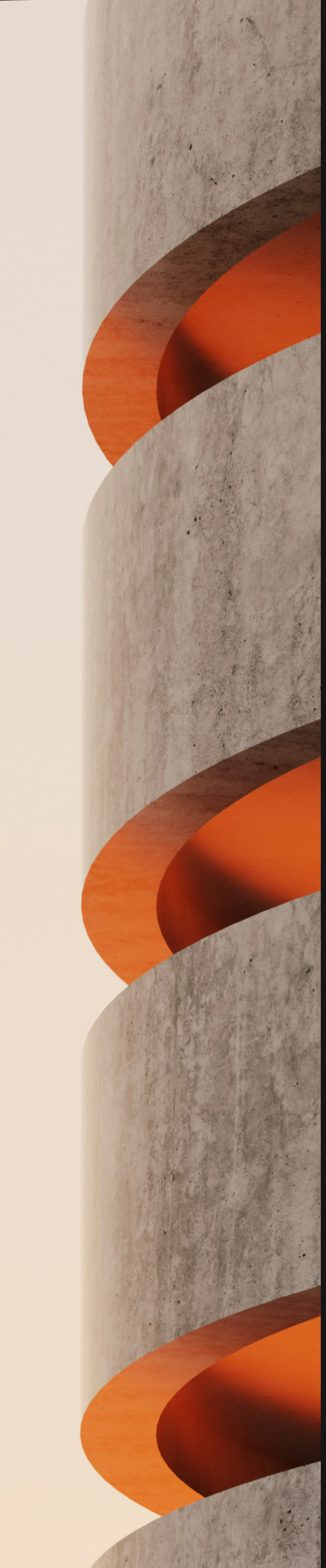
XPRIZE Carbon Removal launched in 2021 with an ambitious goal in mind: To catalyze the global supply of high-quality, cost-effective carbon dioxide removal (CDR) solutions.

Since then, over 1,300 Teams from 88 countries have taken on the challenge and joined the competition. In May 2024, XPRIZE announced the Top 100 most promising carbon removal innovators, after three years of the competition and several rounds of judging. The Top 100 is a collection of leading innovators from 25 countries, representing all CDR pathways: Air, Ocean, Land, Rocks. These teams have made incredible accomplishments in recent years developing new solutions and represent the future of the carbon removal industry. Below are several highlights about the cohort, more data can be found in XPRIZE's Getting to Gigatonne report.

GEOGRAPHIC DISTRIBUTION

HQ Country	
United States	45
Germany	6
United Kingdom	5
Canada	5
Australia	5
China	4
Netherlands	3
Switzerland	2
Philippines	2
New Zealand	2
Mexico	2
Kenya	2
Israel	2
Ireland	2
France	2
Brazil	2
Taiwan	1
South Korea	1
Oman	1
Norway	1
Indonesia	1
India	1
Finland	1
Denmark	1
Austria	1
Total	**100**





CDR PROJECT LANDSCAPE

CDR encompasses a wide array of solutions, each with its own set of co-benefits that extend beyond climate change mitigation alone, and there is already international evidence of a range of CDR project types being advanced around the world. CDR interventions in cities offer a promising avenue for mitigating the impacts of greenhouse gas emissions while simultaneously addressing various environmental, social, and economic challenges. By leveraging the dense infrastructure and resources available in cities, CDR initiatives have the potential to scale up significantly, meaningfully contributing to climate mitigation efforts. While cities are at the forefront of innovation and action, their efforts in deploying CDR solutions can transcend local borders, reflecting a broader commitment to global climate action.

This section delves into the evolving landscape of CDR project deployment relevant to cities, using the XPRIZE Carbon Removal categorization of CDR solution types: Air, Oceans, Land and Rocks. The list of presented projects under each solution type is by no means exhaustive, but is rather intended to highlight a representative sample of the diverse and innovative approaches being implemented in the field. Our exploration encompasses a varied selection of CDR technology applications, both within municipal boundaries and extending beyond them. In some cases, cities may not directly be engaged in the presented projects, but this reflects missed opportunities to engage with highly relevant projects. In others, the project's ability to remove carbon is not its primary focus, but is itself rather an opportune, or engineered, co-benefit.

While some projects are directly urban-focused solutions or relating to integration with urban infrastructure, the relevance of others to cities may relate to community engagement and participation, scalability and cost-effectiveness, policy and regulatory implications. The relevance of each project type and subtype will vary for individual cities, based on their geographic characteristics, natural, human and financial resources, as well as a myriad of context-specific factors. A portfolio approach to CDR, combining different carbon removal methods, can help strike the right balance between durability and costs, leveraging the various co-benefits of both durable and less durable removal solutions, while maximizing their impact on multiple sustainable development goals.

CDR PROJECT LANDSCAPE:

Air

Direct Air Capture (DAC) stands out as a promising CDR solution with the potential to transform future climate mitigation efforts, including in urban environments. DAC encompasses various subtypes, including: i) solid sorbent-based capture; ii) solvent-based capture; iii) electrochemical capture; and iv) membrane-based capture. Sorbent-based capture involves adsorbing CO_2 onto solid materials, while solvent-based capture relies on chemical solvents to absorb CO_2 from the air. Membrane-based capture employs selective membranes to separate CO_2 from other gasses. While certain DAC approaches have demonstrated feasibility at pilot scales, achieving widespread deployment and cost-effectiveness remains a key challenge.

In cities, DAC holds potential because of its versatility and scalability. By deploying DAC systems within urban environments, cities can directly target emissions hotspots and capture CO_2 from ambient air, irrespective of the source. This not only allows for localized carbon removal but also offers opportunities for synergies with existing infrastructure and urban development initiatives. DAC installations could be integrated into buildings, transportation hubs, and industrial complexes, leveraging existing energy and transportation networks to optimize efficiency and minimize logistical challenges. However, DAC deployment in cities would require targeted technological innovation, significant resources, including capital investment, space for infrastructure, energy, and access to financial incentives or regulatory support, necessitating careful consideration of costs and benefits for sustainable implementation.

The illustrative projects presented exclusively use solid sorbent technology, which is the most advanced DAC technology at present. It can be foreseen that as other technologies develop, their applications will be more widespread; this includes modular DAC that could be integrated in existing infrastructure (e.g. Skytree, currently only used for carbon capture and utilization). City interventions in the below project cover: i) project financing; ii) collaboration and partnerships through municipally-owned companies; and iii) project permitting.

DAC – TO – CONCRETE PROJECT

CDR Solution Type:
Air

CDR Solution Subtype:
Solid Sorbent DAC

Location:
Flagstaff, Arizona, USA

General Description:

The 4 Corners Carbon Coalition has awarded $150,000 to develop an on-site, fully-integrated DAC-to-concrete manufacturing facility in Flagstaff, Arizona. Spearheaded by CarbonBuilt and Aircapture, in collaboration with Block-Lite, the project aims to dramatically reduce the embodied carbon of concrete blocks compared to traditional methods. CarbonBuilt's technology will be used on-site at Block-Lite, integrating CO_2 captured by Aircapture into the concrete manufacturing process. This initiative not only advances climate goals but also sets a new model for modular DAC, where captured carbon is removed in durable, commercial products. With the City of Flagstaff's support and the involvement of key stakeholders, including CarbonBuilt, Aircapture, and Block-Lite, this project provides an alternative model to the construction industry.

City Role:

4 Corners Carbon Coalition, who provided financing to this project, is a municipal initiative pooling resources from local governments. By providing financing and support for the initiative, the Coalition demonstrates Flagstaff's proactive approach to addressing the climate crisis at the community level. The establishment of the facility not only advances environmental goals but also stimulates economic growth and job creation.

DAC - TO - CONCRETE PROJECT

CDR Solution Type:
Air

CDR Solution Subtype:
Solid Sorbent DAC

Location:
Tracy, California, USA

General Description:

Heirloom launched a commercial DAC facility, a mineralization plant located in Tracy, California. The facility has a capture capacity of up to 1,000 tons of CO_2 per year, achieved through innovative limestone-based technology. Powered entirely by renewable energy sourced locally, the facility operates in collaboration with CarbonCure Technologies to permanently sequester captured CO_2 in concrete, supporting construction projects statewide. Spearheaded by Heirloom, the project involves a diverse array of stakeholders, including government officials, industry leaders, and local community members. With a robust community governance model in place and adherence to responsible deployment principles, the facility not only addresses environmental imperatives but also fosters job creation and community engagement.

City Role:

Ava Community Energy, which supplies the project with renewable energy, is a public agency established by local cities. By approving zoning and permitting for the plant, Tracy demonstrates its commitment to supporting innovative solutions for carbon removal within its jurisdiction. This is an example of fostering sustainable development and addressing global environmental challenges at the local level.

PROJECT ORCA

CDR Solution Type:
Air

CDR Solution Subtype:
Solid Sorbent DAC

Location:
Reykjavik, Iceland

General Description:

Orca is a large-scale direct air capture and storage plant, located in Iceland near Hellisheidi. Launched in September 2021, this pioneering facility, developed by Climeworks in partnership with Carbfix, has an annual capture capacity of up to 4,000 tons of CO_2, facilitated by eight collector containers employing state-of-the-art technology designs. The project is powered by the renewable energy supplied by the nearby Hellisheidi Geothermal Power Plant.

City Role:

The relevance of Orca extends to cities through its stakeholders (Carbfix and Hellisheidi Geothermal Power Plant), some of which are fully or partially owned by municipalities. Orca demonstrates the feasibility of large-scale carbon dioxide removal, and also underscores the crucial role of public-private partnerships in advancing carbon removals.

PROJECT HUMMINGBIRD

CDR Solution Type:
Air

CDR Solution Subtype:
Solid Sorbent DAC

Location:
Naivasha, Kenya

General Description:

Project Hummingbird is led by Octavia Carbon, a DAC company, and Cella Mineral Storage, a carbon mineralization pioneer. Located in Naivasha along the Great Rift Valley, Kenya, this pilot DAC facility leverages Kenya's unique geological and geothermal attributes to capture and store 1,000 tons of CO_2 annually. It is expected to start operations in October 2024, and aims to deliver carbon removal credits certified by Puro.earth, setting a new industry standard for trusted carbon removals in Kenya. This project demonstrates how local projects contribute to the implementation of national climate strategies.

City Role:

While there is no direct city intervention in Project Hummingbird, its significance lies in showcasing the potential application and opportunities for CDR solutions and DAC in regions like the global South. It also sets a precedent for cities in the global South to explore similar solutions, fostering innovation and leveraging partnerships and collaborations.

CDR PROJECT LANDSCAPE:

Oceans

Oceans present a rising platform for CDR. Types of ocean CDR solutions include algae cultivation, biomass sinking, artificial upwelling and downwelling, ocean alkalinity enhancement, nutrient fertilization, electrochemical CO_2 separation and ocean ecosystem restoration and management. Ocean alkalinity enhancement involves the addition of alkaline substances, such as calcium hydroxide, to seawater to increase its capacity to absorb CO_2. Similarly, nutrient fertilization focuses on stimulating phytoplankton growth through the addition of nutrients, which can enhance the ocean's ability to sequester carbon. The restoration and management of coastal ecosystems – such as seagrass, corals and mangroves – provides a range of environmental and biodiversity services, as well as carbon sequestration.

In urban contexts, the application of ocean-based CDR solutions presents unique opportunities and challenges. Cities located near coastlines can play a significant role in implementing and supporting these initiatives. For instance, coastal cities have much to gain from the restoration and management of coastal ecosystems, which can not only mitigate carbon emissions but also enhance coastal resilience and support marine biodiversity, thereby realizing multiple co-benefits for both urban and marine environments. Cities can also invest in research and development efforts and can collaborate with academia and civil society to monitor and mitigate potential ecological impacts of ocean-based CDR interventions. As many of these solutions are still nascent, it is essential to recognize potential trade-offs, such as impacts on marine ecosystems and biodiversity, which require careful consideration and mitigation strategies.

The predominant solution subtype in the projects highlighted is ocean ecosystem restoration and management, emphasizing the preservation and revitalization of coastal ecosystems such as mangroves, salt marshes, and seagrass beds. These projects underscore the pivotal role of coastal cities in implementing CDR solutions. Despite the demonstrated success of some projects, Ocean-based projects appear relatively less developed compared to other CDR solution types, though they offer particular opportunities to coastal cities. This gap suggests a need for increased research, development, and innovation in leveraging ocean-based strategies for carbon removal. While the projects showcased here exhibit promising approaches, there remains a call for further exploration and refinement to maximize their effectiveness in mitigating climate change and promoting coastal resilience.

MANGROVE RECLAMATION PROJECT

CDR Solution Type:
Oceans

CDR Solution Subtype:
Ocean Ecosystem Restoration and Management

Location:
Miami, Florida, USA

General Description:

The Reclamation Project is an innovative eco-art initiative that harnesses community engagement to restore South Florida's coastal ecosystems through mangrove reforestation. By using vertical gardens composed of mangrove seedlings displayed on retail windows along Miami Beach's Lincoln Road, the project prompts residents to reimagine the natural landscape before urban development. Over the years, this community-driven effort, facilitated by the Frost Science Museum, has engaged over 8,000 volunteers and restored more than 25 acres of coastal habitats along Biscayne Bay. Through exhibitions, the project aims to raise awareness about mangrove destruction while fostering community engagement in ecological restoration. While the project does not achieve carbon removals at scale, its success lies in its ability to merge art, environmental activism, and community involvement, creating a powerful platform for dialogue on urban ecology and sustainability.

City Role:

The project holds significant relevance for the city as it embodies a collaborative effort between community members, local government, museums, schools, and foundations to restore coastal ecosystems. Engagement and support from the city council, museums, schools, and other foundations demonstrate a collective commitment to environmental stewardship and urban sustainability. By involving volunteers in mangrove reforestation efforts and hosting exhibitions in public spaces like museums and schools, the project fosters community engagement and awareness about the importance of preserving natural habitats in urban environments. This grassroots initiative not only revitalizes coastal ecosystems but also strengthens community bonds and promotes a culture of environmental responsibility within the city.

CAPTURA'S DIRECT OCEAN CAPTURE PILOT

CDR Solution Type:
Oceans

CDR Solution Subtype:
Electrochemical CO_2 Separation

Location:
Los Angeles, California, USA

General Description:

Captura's Direct Ocean Capture (DOC) technology is operational at public-private ocean institute AltaSea at The Port of Los Angeles with an end-to-end system capable of removing 100 tons of CO_2 per year. Using only seawater and renewable energy as inputs, Captura DOC is engineered to harness the natural carbon removal powers of oceans to deliver a highly scalable and low-cost climate tool that offers ocean acidification as a co-benefit without by-products or ocean additives. This pilot is designed for demonstration of Captura's process in real-world conditions, continued validation of DOC's benign impact on ocean health, ongoing MRV modeling and data collection, and stakeholder engagement and community education activities. Captura has partnered with local organizations in this effort to contribute to industry knowledge-building, including Holdfast, in support of its aquaculture research, and SCCWRP (Southern California Coastal Water Research Project), to conduct commercial-scale biogeochemical ocean models.

City Role:

Spun out from Caltech, Captura operates at AltaSea in the Port of Los Angeles, emphasizing the role of coastal cities in marine CDR deployment. Captura actively supports Los Angeles' blue economy through community engagement, professional development, education, and workforce enrichment initiatives.

In its current role, Los Angeles serves as a crucial hub for DOC research and deployment. The city could maximize its impact, for example by setting local CDR targets, facilitating permitting processes, integrating DOC into existing industrial facilities like desalination plants, fostering local innovation, designing funding opportunities and running public information campaigns. This pilot demonstrates how coastal cities like Los Angeles are pivotal in advancing marine CDR technologies and addressing climate change impacts.

YOKOHAMA BLUE CARBON PROJECT

CDR Solution Type:
Oceans

CDR Solution Subtype:
Ocean Ecosystem Restoration and Management

Location:
Yokohama, Japan

General Description:

The Blue Carbon Project in Yokohama is at the forefront of Japan's commitment to carbon neutrality by 2050. Located in the port city of Yokohama, the project harnesses coastal marine ecosystems to mitigate carbon emissions and combat climate change. Leveraging the principles outlined by the Yokohama council, the project focuses on the capture and storage of blue carbon, derived from coastal and marine resources like mangroves, salt marshes, and seagrass beds. By adopting rigorous implementation standards and promoting transparency, the project aims to ensure the integrity, consistency, accuracy, transparency, and maintainability of its actions. Stakeholders involved include the Yokohama council, the Japanese Ministry of Economy, Trade and Industry, the Ministry of the Environment, as well as industry players like Nippon Steel and technology development organizations like NEDO. Through innovative approaches such as the production of marine biomass for steel production and the exploration of carbon-neutral materials, the project not only contributes to decarbonization efforts but also fosters economic growth and job creation. By highlighting the importance of blue carbon in mitigating global warming and emphasizing the ocean's role in achieving carbon neutrality, Yokohama sets a precedent for coastal cities worldwide in promoting environmental sustainability and forging a path towards a low-carbon future.

City Role:

The project holds relevance for a city like Yokohama, which plays an important role in global trade and industry, serving as a model for urban centers worldwide. Through the project's emphasis on harnessing coastal marine ecosystems, Yokohama not only mitigates its carbon footprint but also safeguards its natural resources and fosters resilience against climate change impacts such as sea-level rise and extreme weather events. The project demonstrates that cities can capitalize on ocean resources to address global climate change. Moreover, by ensuring robust implementation standards and fostering transparency, the project not only generates carbon credits but also promotes local economic growth and job creation, thereby unlocking co-benefits for the city's inhabitants. The project serves as an indicator of Yokohama's commitment to sustainability while incentivizing further investment in low-carbon initiatives.

OCEAN ALKALINITY ENHANCEMENT PROJECT

CDR Solution Type:
Oceans

CDR Solution Subtype:
Ocean Ecosystem Restoration and Management

Location:
Manoa, Hawaii, USA
San Francisco, California, USA

General Description:

The Ocean Alkalinity Enhancement Project is a research project aimed at assessing the efficacy and efficiency of using alkalinity to remove carbon dioxide from the atmosphere, thus both addressing climate change and ocean acidification. Led by researchers from the University of Hawaii at Mānoa, this project involves partnerships with local stakeholders from the San Francisco Bay, including a wastewater treatment plant, to conduct experiments adding alkalinity to ocean water. The project will evaluate the impact of alkalinity release on carbon removal. With funding from the National Oceanographic Partnership Program and the U.S. Department of Energy, this research not only advances understanding of ocean-based CDR but also addresses concerns about its effects on marine ecosystems, particularly corals and crustose coralline algae. By promoting inclusivity and community engagement, the project seeks to ensure that its findings are grounded in diverse perspectives and contribute to informed decision-making regarding climate mitigation strategies.

City Role:

While direct city intervention may not be explicit, collaboration with the East Bay Municipal Utility District underscores the importance of municipal entities in advancing innovative solutions for climate mitigation. Driven by academia, the project not only contributes to scientific knowledge but also fosters a collaborative ecosystem that promotes sustainable practices and informs local decision-making. Moreover, the opportunity for partnerships highlights the potential for cities to play a catalytic role in facilitating interdisciplinary research and implementing cutting-edge technologies to address climate change and ocean acidification, ultimately benefiting both local communities and the global environment.

CDR PROJECT LANDSCAPE:

Land

Land-based solutions offer a wide range of strategies to sequester carbon from the atmosphere. These include agricultural and grassland CDR, ecosystem restoration and management, biomass sequestration in the built environment, biomass burial, biomass to energy with CO_2 capture and storage (BECCS), and biological and thermal conversion of biomass. These solutions span the conventionally named 'nature-based' and 'technology-based' CDR solutions. However, they are all based on the ability of biomass and soils to absorb and store CO_2 through photosynthesis. These solutions are among the most developed CDR technologies available today.

In urban contexts, land-based CDR solutions offer significant potential to address carbon emissions and enhance environmental sustainability. Cities can implement afforestation and reforestation initiatives in urban parks, green spaces, and degraded lands to enhance carbon sequestration while providing numerous co-benefits such as improved air quality, biodiversity conservation, and recreational opportunities for residents. Soil carbon sequestration practices can be integrated into urban agriculture, community gardens, and landscaping projects, enhancing soil health, water retention, and urban resilience while sequestering carbon. BECCS also holds huge promise in that it can be applied to municipal waste management and certain industrial facilities. However, trade-offs – such as land competition with other urban development needs, potential displacement of existing land uses, and biomass sustainability and availability – must be carefully managed to ensure equitable and sustainable implementation of land-based CDR solutions in cities.

The projects in the below table encompass a diverse range of land-based CDR solution subtypes, predominantly focusing on BECCS, thermal conversion of biomass (biochar), and terrestrial ecosystem restoration and management. This reflects the intersection of urban development and environmental sustainability and showcasing the potential for cities to lead in carbon sequestration efforts while addressing local environmental challenges. This is a broad category of CDR solutions, spanning nature-based and technology-based removals. The latter underscore the role of cities in implementing large-scale carbon removal technologies.

Terrestrial ecosystem restoration and management projects highlight the importance of nature-based solutions (NbS) in urban sequestration efforts, as well as the range of co-benefits that are generated, including soil enrichment, stormwater management and urban greening. These projects emphasize the role of cities in promoting biodiversity and enhancing green infrastructure but also showcase innovative approaches to financing and community engagement. While carbon removal may not always be the primary objective of such initiatives, they offer valuable insights into holistic approaches to urban sustainability and resilience, particularly in location-specific context.

A Note on Biomass Carbon Removal and Storage

A South Pole and Bellona report demonstrated that, in Amsterdam alone, an annual volume of nearly 1 Mt of biogenic CO_2 could be removed via Biomass Carbon Removal and Storage (BiCRS) from biomass power generation, biogas production, waste-to-energy and wastewater treatment – not accounting for all biogenic emissions in the area. This represents ~25% of the City's current emissions.

HELSINGBORG BIOCHAR INITIATIVE

CDR Solution Type:
Land

CDR Solution Subtype:
Thermal Conversion of Biomass (Biochar)

Location:
Helsingborg, Sweden

General Description:

The Helsingborg Biochar Initiative is a project that aims to remove carbon dioxide emissions and enhance urban greenery through innovative technology and collaboration. Spearheaded by the City of Helsingborg in partnership with NSR, its municipal waste company, and supported by Bloomberg Philanthropies, the project involves the construction of a biochar production plant capable of annually converting around 7,000 tons of garden waste into approximately 1,500 tons of biochar. This biochar will be used to enrich soil, mitigate stormwater runoff, and promote the growth of trees. The initiative builds upon the success of Stockholm's Biochar Project to surpass it in scale, with Helsingborg aiming to produce five times the amount of biochar. Furthermore, the project includes the establishment of a competence center for biochar development, positioning Helsingborg as a hub for research, innovation, and experimentation in the emerging biochar industry. By leveraging expertise from exemplar cities like Stockholm and fostering collaboration among municipalities, academics, and the private sector, Helsingborg is a new model for urban sustainability and economic development, setting a global standard for biochar implementation and knowledge sharing.

City Role:

Through a joint investment by the city and the private sector, this initiative exemplifies a collaborative approach to tackling environmental challenges while fostering economic growth. By co-driving the initiative with NSR, the municipal waste company, Helsingborg ensures that both public and private interests are aligned towards achieving common goals. Moreover, intra-city partnerships are crucial as they enable efficient resource use and knowledge exchange among different departments and stakeholders. This integrated approach not only maximizes the impact of the biochar project but also sets a precedent for cities worldwide to engage in innovative partnerships for holistic urban development. Promoting innovation has led the city to becoming a biochar hub, with a biochar summit being held there last year.

CARBON REMOVAL PARK BALTIC SEA

CDR Solution Type:
Land

CDR Solution Subtype:
Thermal Conversion of Biomass (Biochar)

Location:
Grevesmühlen, Germany

General Description:

The Carbon Removal Park Baltic Sea, spearheaded by Novocarbo, is a pioneering endeavor in addressing climate change through innovative technology and collaborative partnerships. Officially opened in October 2023, the park integrates CDR technologies with green heat generation, removing 3,200 tons of CO_2 annually while generating 6,600 MWh of climate-neutral heat and producing 1,700 tons of biochar for agricultural use. Using state-of-the-art pyrolysis technology from PYREG, the park converts biogenic residues into biochar, locking carbon and producing climate-neutral waste heat, which is integrated into the municipal district heating network by Stadtwerke Grevesmühlen. The collaboration between Novocarbo and Stadtwerke Grevesmühlen is an example of the potential for cleantech startups and municipal utilities to drive decarbonization and removal efforts, with plans for further expansion and replication of the model globally by 2033.

City Role:

By actively involving a municipal waste company like Stadtwerke Grevesmühlen, the project not only demonstrates the potential for collaboration between public and private entities but also highlights the importance of integrating municipal services into climate mitigation efforts. The provision of climate-neutral heat by the project contributes to greening the district heating network, reducing reliance on fossil fuels, and enhancing local air quality. Additionally, the project showcases innovative approaches to carbon removal and heat generation, setting a precedent for other cities to follow suit in their decarbonization efforts and fostering a more resilient urban environment.

HAFSLUND OSLO CELSIO WASTE-TO-ENERGY

CDR Solution Type:
Land

CDR Solution Subtype:
Biomass to Energy with CO_2 Capture and Storage

Location:
Oslo, Norway

General Description:

The Hafslund Oslo Celsio project, previously known as Fortum Oslo Varme, aims to implement carbon capture technology to mitigate emissions from their waste-to-energy operations in Oslo. With construction starting in 2022, the project encountered setbacks due to increased cost estimates, leading to a current pause in progress as cost reduction strategies are explored. The project targets the capture of up to 400,000 tonnes of CO_2 annually, a significant step towards addressing the climate impact of the city's waste-to-energy activities. With approximately 60% of emissions stemming from biogenic sources, the carbon capture initiative is expected to remove around 200,000 tonnes of CO_2 from the carbon cycle each year. Hafslund Oslo Celsio, jointly owned by Hafslund Eco, Infranode, and HitecVision, is integral to Oslo's pursuit of ambitious climate goals, with carbon capture aligning closely with both city and company strategies for sustainable energy production and climate change mitigation.

City Role:

With the majority ownership by the city itself, this initiative underscores Oslo's commitment to leading the way in environmental stewardship. Similarly to BECCS Stockholm, the project directly addresses the environmental impact of municipal waste management, aligning closely with the city's ambitious climate goals, while simultaneously advancing towards a more sustainable and environmentally friendly approach to waste management.

BECCS STOCKHOLM

CDR Solution Type:
Land

CDR Solution Subtype:
Biomass to Energy with CO2 Capture and Storage

Location:
Stockholm, Sweden

General Description:

The BECCS facility developed by Stockholm Exergi represents a significant advancement in carbon capture technology, particularly in the realm of bio-energy with carbon capture and storage (BECCS). This facility will play a pivotal role in mitigating climate change by permanently removing up to 800,000 tonnes of CO_2 from the atmosphere annually, through the integration of carbon capture units with existing biomass-based power infrastructure. With the attainment of necessary environmental permits and a planned construction start in 2025, the BECCS facility underscores the city's commitment to decarbonization and the transition to a low-carbon economy.

Recently, Microsoft and Stockholm Exergi signed a contract for the world's largest permanent carbon removal deal to date. Through this partnership, Stockholm Exergi commits to delivering 3.33 million tonnes of permanent carbon removals to Microsoft, commencing in 2028 and spanning a decade. With rigorous quality standards, sustainable biomass sourcing, and comprehensive monitoring and reporting mechanisms in place, the deal showcases the importance of collaborations between the private and public sectors, as Stockholm Exergi is part-owned by the city.

City Role:

BECCS Stockholm holds profound relevance for the city, given its direct involvement, investment, and part-ownership of the initiative. Through its partnership with Stockholm Exergi, the city demonstrates a proactive stance in addressing climate change and advancing sustainable energy solutions. The integration of carbon capture technology with municipal waste management and energy production aligns with the city's commitment to reducing greenhouse gas emissions and transitioning towards a low-carbon economy. As a part-owner of the project, the city not only shares in the environmental benefits but also stands to reap economic returns, contributing to local job creation and economic development. By leveraging its resources and expertise, the city plays a crucial role in driving innovation and accelerating the adoption of carbon removal technologies, setting an example for other municipalities worldwide to follow suit in their climate mitigation efforts.

DUBLIN CARBON SEQUESTRIAN PILOT PROJECT

CDR Solution Type:
Land

CDR Solution Subtype:
Agricultural & Grassland CDR

Location:
Dublin, California, USA

General Description:

The Carbon Sequestration Pilot Project, a collaborative effort between the City of Dublin, StopWaste, and the University of California Merced, aims to investigate the efficacy of carbon sequestration in urban landscapes. By applying compost to test plots at varying depths, the project seeks to assess its impact on soil carbon uptake and evaluate associated maintenance and irrigation requirements. With a timeline spanning from March 2023 to spring 2024, researchers are conducting regular soil and gas sampling to monitor changes. While being implemented at a small-scale, the project is an example of localized efforts to mitigate climate change and enhance landscape resilience. Key stakeholders include municipal authorities, waste management organizations, and academic institutions, highlighting a multidisciplinary approach to sustainable urban development.

City Role:

By exploring the potential of carbon farming in urban landscapes, the initiative offers a tangible solution for reducing atmospheric CO_2 levels and enhancing environmental resilience. Through the strategic application of compost in public spaces, the project not only aims to sequester carbon but also seeks to improve soil health and reduce maintenance needs, ultimately contributing to more sustainable and livable urban environments.

FREETOWN THE TREETOWN

CDR Solution Type:
Land

CDR Solution Subtype:
Terrestrial Ecosystem Restoration and Management

Location:
Freetown, Sierra Leone

General Description:

The Freetown The Treetown initiative, spearheaded by Mayor Yvonne Aki-Sawyerr, is a project aimed at combating rapid deforestation and mitigating the risk of natural disasters in Freetown, Sierra Leone. The campaign, intricately linked to the Transform Freetown strategy, has set a bold target of planting and nurturing a million trees by the end of 2022. Through a blend of community engagement, innovative digital technologies, and diverse financing mechanisms, the project has already made significant strides, with 560,000 trees planted and 578 hectares of urban land restored within the first two years. Targeting various areas strategically, including informal settlements, water catchments, and coastal zones, the initiative not only seeks to increase green cover but also addresses specific environmental challenges such as heat stress, air pollution, water security, and coastal erosion. Moreover, the project has created over 1,000 green jobs, predominantly benefitting youths and women. One of the project's notable innovations lies in its financing model, which involves tokenizing trees to attract private investment for long-term sustainability. By integrating with Freetown's climate action planning and collaborating with neighboring municipalities, Freetown The Treetown sets a precedent for scalable, community-driven urban reforestation efforts with far-reaching environmental and socio-economic benefits.

City Role:

The project is an example of successful urban reforestation initiatives and emphasizes the role of local leadership in addressing environmental challenges. By focusing on co-benefits beyond just carbon sequestration, such as reducing disaster risks and enhancing community resilience, the project underscores the multifaceted advantages of green infrastructure in urban settings. Moreover, its innovative financing model, which leverages tokenization and private investment, showcases a sustainable approach to funding nature-based solutions.

CDR PROJECT LANDSCAPE:

Rocks

Rock-based CDR solutions encompass various techniques aimed at leveraging natural geological processes to sequester carbon from the atmosphere. This includes mineralization of mined rocks, mine and industrial waste, storage in sedimentary reservoirs and calcination of minerals.

Carbon mineralization is a natural process occurring over a period of hundreds of thousands of years whereby minerals inside rocks react with CO_2 to form stable carbonates, effectively locking away carbon for long periods. Enhanced rock weathering (ERW) accelerates the natural process of rock weathering, which absorbs CO_2 and forms stable carbonates. Direct injection into geological formations involves injecting captured CO_2 into underground reservoirs, such as depleted oil or gas fields or deep saline aquifers, where it is stored permanently.

Cities can explore the implementation of mineral carbonation techniques in urban infrastructure projects, such as building materials production or construction of carbon-negative buildings, to sequester carbon emissions directly within the built environment. Enhanced weathering strategies could be applied in urban environments such as green spaces, parks, or urban agriculture projects, utilizing crushed rock or minerals to enhance soil carbon storage while mitigating urban heat island effects. According to some estimates in the City of Amsterdam, if all available traffic, sport, agrarian, recreation, forest terrain and rooftops were used for enhanced rock weathering, up ~1 Mt CO_2 (cumulative) could be removed from the atmosphere. Co-benefits may also include improved air quality, soil fertility and urban resilience. However, the scalability and feasibility of rock-based CDR solutions in urban areas may be limited by factors such as land availability, infrastructure requirements, and potential environmental impacts.

At the forefront of innovation, rock-based CDR solutions are still nascent, but the projects presented below provide an illustration of how they can be particularly relevant for cities. Links with the materials and the built environment, particularly, highlight the synergistic potential of these solutions with urban planning. Various research projects are further exploring the potential of enhanced rock weathering on agricultural and other types of land, as well as co-benefits and trade-offs.

CO_2 MINERALIZATION STORAGE: NEUSTARK X HEIM

CDR Solution Type:
Rocks

CDR Solution Subtype:
Mineralization of Mine or Industrial Waste

Location:
Berlin, Germany

General Description:

Neustark, a Swiss climate-tech pioneer, established a CO_2 storage site in collaboration with Berlin-based construction and recycling company Heim, the first commercial site for permanent CO_2 storage in the EU. Neustark mineralizes CO_2 captured from biogas plants into demolition concrete, permanently storing it and thus removing it from the atmosphere. The site in Germany, located in Berlin, can store over 1,000 tons of CO_2 annually. With twelve storage sites already operational in Switzerland and Germany, Neustark aims to scale up its impact, with plans to launch thousands of CO_2 storage sites globally in partnership with recycling partners. Notable stakeholders include biogas plants, biomethane trading companies, and corporate clients like Microsoft and UBS, who purchase carbon removal certificates to achieve net-zero targets.

City Role:

Although there is no direct intervention from the city of Berlin, the project highlights the potential for partnerships between municipally owned companies and innovative climate-tech solutions like Neustark's, demonstrating how collaborations can advance carbon sequestration efforts at the local level. Moreover, the sourcing of CO_2 from a partly municipally-owned biogas plant underscores the interconnectedness of municipal infrastructure with climate initiatives, emphasizing the role of public-private partnerships in achieving carbon neutrality. This project sets a precedent for leveraging municipal resources and expertise to drive climate innovation.

CO_2-INJECTED CONCRETE FOR CURB RAMPS: CITY OF SAN JOSÉ X CARBONCURE

CDR Solution Type:
Rocks

CDR Solution Subtype:
Calcination of Minerals

Location:
San José, California, USA

General Description:

The City of San José's innovative carbon removal initiative, launched in November 2022, focuses on utilizing CarbonCure's cutting-edge technology to create carbon-negative concrete for public infrastructure. This project revised concrete specifications to require low-carbon mixes for ADA (Americans with Disabilities Act)-compliant curb ramps. By partnering with CarbonCure, Central Concrete, and Spencon Construction, the city integrated post-industrial CO_2 into the concrete, reducing cement content and incorporating supplementary materials like slag and fly ash. This mineralization process permanently embeds CO_2 within the concrete as calcium carbonate. With plans to construct or upgrade around 2,000 curb ramps annually and 18,000 remaining, this initiative promises substantial carbon removal and sets a precedent for sustainable construction efforts in San José.

City Role:

Adopting carbon-negative concrete technology is highly relevant for cities as it aligns with urban sustainability goals and climate action plans. The city's role involves updating construction standards, fostering partnerships with innovative companies like CarbonCure, and implementing projects that both reduce and remove carbon emissions. Co-benefits include enhanced infrastructure durability and improved air quality. The project also sets a precedent for other municipalities to follow, demonstrating leadership and contributing to broader environmental and public health improvements.

CONCLUSION

The deployment of CDR projects in cities offers a transformative opportunity to address climate change while achieving broader urban development goals. Cities are uniquely positioned to advance carbon removals in a way that maximizes impact through synergies across social, economic and environment objectives. With this framing, cities can develop CDR policy that relieves, rather than burdens, city administrations.

Key takeaways from this report highlight the diverse pathways cities can adopt to generate significant impact.

Planning to neutralize residual emissions

A credible carbon neutrality strategy must include plans to neutralize residual emissions after all feasible reductions. This involves quantifying these emissions and outlining the CDR approaches to be used, such as nature-based solutions and negative emission technologies.

Different pathways of engagement for impact

Cities can assume various roles – as strategizer, regulator, service provider, innovator, funder or convener – to advance CDR initiatives, depending on their local context, priorities, and capacities.

Co-benefits first approach

Adopting a "co-benefits first" approach allows cities to prioritize CDR projects that also address other sustainable development goals. This enhances the effectiveness and efficiency of carbon removal efforts while contributing to building resilient, equitable and sustainable cities.

Ambitious policy frameworks

A robust and ambitious policy framework is essential to support CDR vision and implementation. While national and supranational policies play a significant role, cities have access to a vital policy toolkit that can enhance their climate neutrality plans and tap into co-benefits.

Supporting innovative technologies and companies

Cities can support innovative CDR technologies and companies, crucial to the achievement of the required scale. This support can boost local startups and create long-term opportunities.

Reimagining cities as carbon sinks

Embracing the concept of cities as carbon sinks can shift urban planning paradigms. By integrating nature-based solutions and technological innovations, cities can enhance their capacity to absorb carbon, improve local biodiversity, air quality and residents' quality of life.

Big questions remain to be addressed to unlock the full potential of City CDR, as described in this baselining report. How can cities account for the removals realized within their municipal boundaries, while preventing double counting of mitigation results? Which carbon removal methods are the most promising for different city archetypes? Where can cities intervene in the project value chain? How can cross-policy linkages be established in practice? How to most appropriately embed CDR objectives in non-climate policies? A subsequent report will look into these questions in greater detail.

CONCLUSION:

Call to Action

Cities have the potential to emerge as critical nodes for the development and deployment of carbon removals. The interconnectedness of urban and global climate challenges highlights the necessity for collaborative action across all levels of governance and society.

City leaders, policymakers, and stakeholders are called to prioritize and expedite CDR development efforts. The urgency of addressing climate change demands immediate action, and CDR presents a transformative opportunity to create more sustainable and resilient urban environments for both current and future generations. Cities must seize this opportunity to lead by example, integrating CDR into their climate and sustainability agendas, and setting a precedent for global action towards a more sustainable future and positive living environment.

PATHWAYS TO NET-ZERO CITIES

The Role of Cities in Advancing Carbon Removal

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GLOBAL CARBON REMOVAL PARTNERSHIP

JUNE 2024