Survive and Thrive

Why BC needs a CO_2 removal strategy now

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The Pacific Institute for Climate Solutions (PICS) develops impactful, evidence-based climate change solutions through collaborative partnerships which connect private and public sector solution seekers with experts from BC's four leading research universities. PICS is hosted and led by the University of Victoria, in collaboration with the University of British Columbia, Simon Fraser University, and the University of Northern British Columbia.

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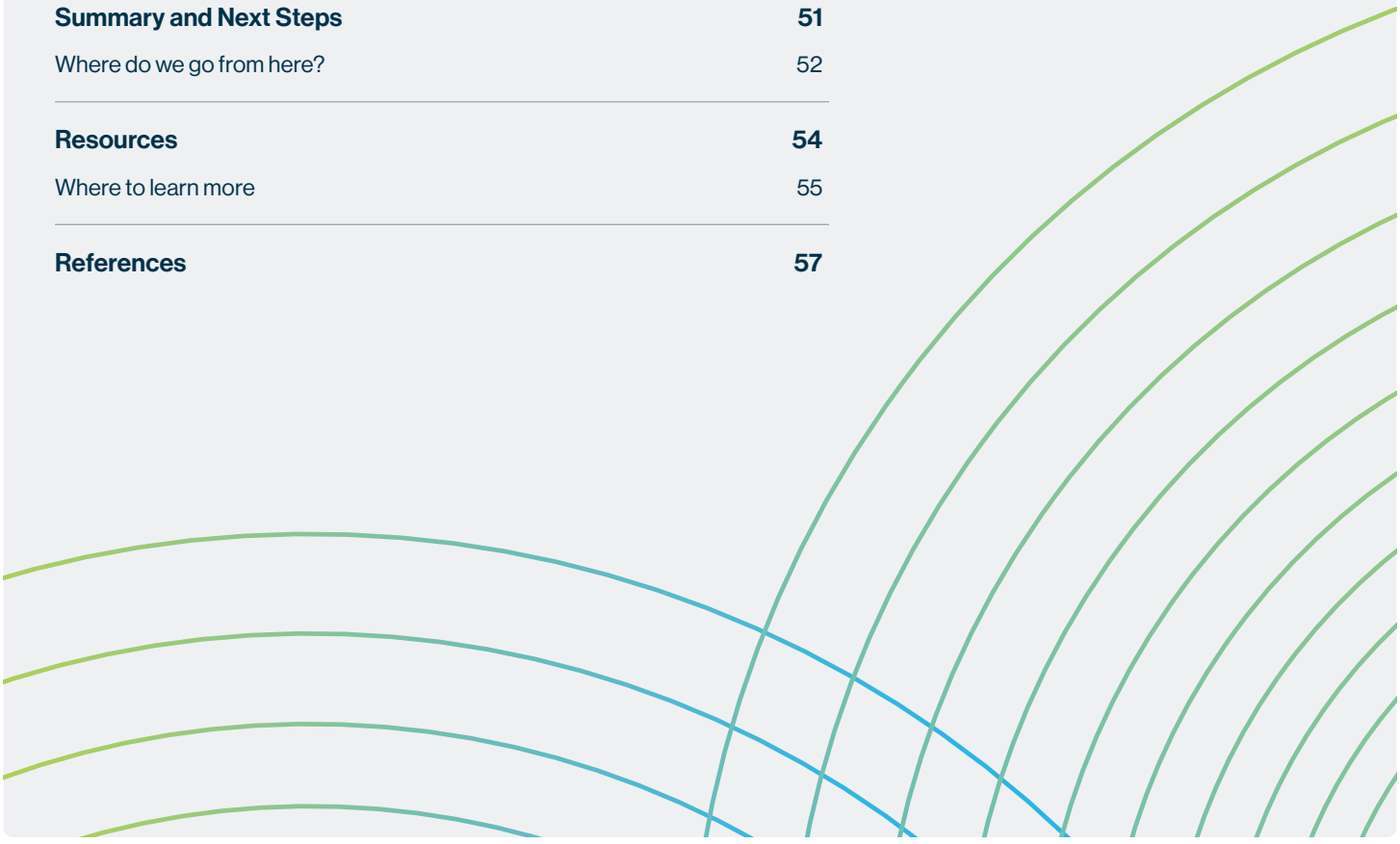

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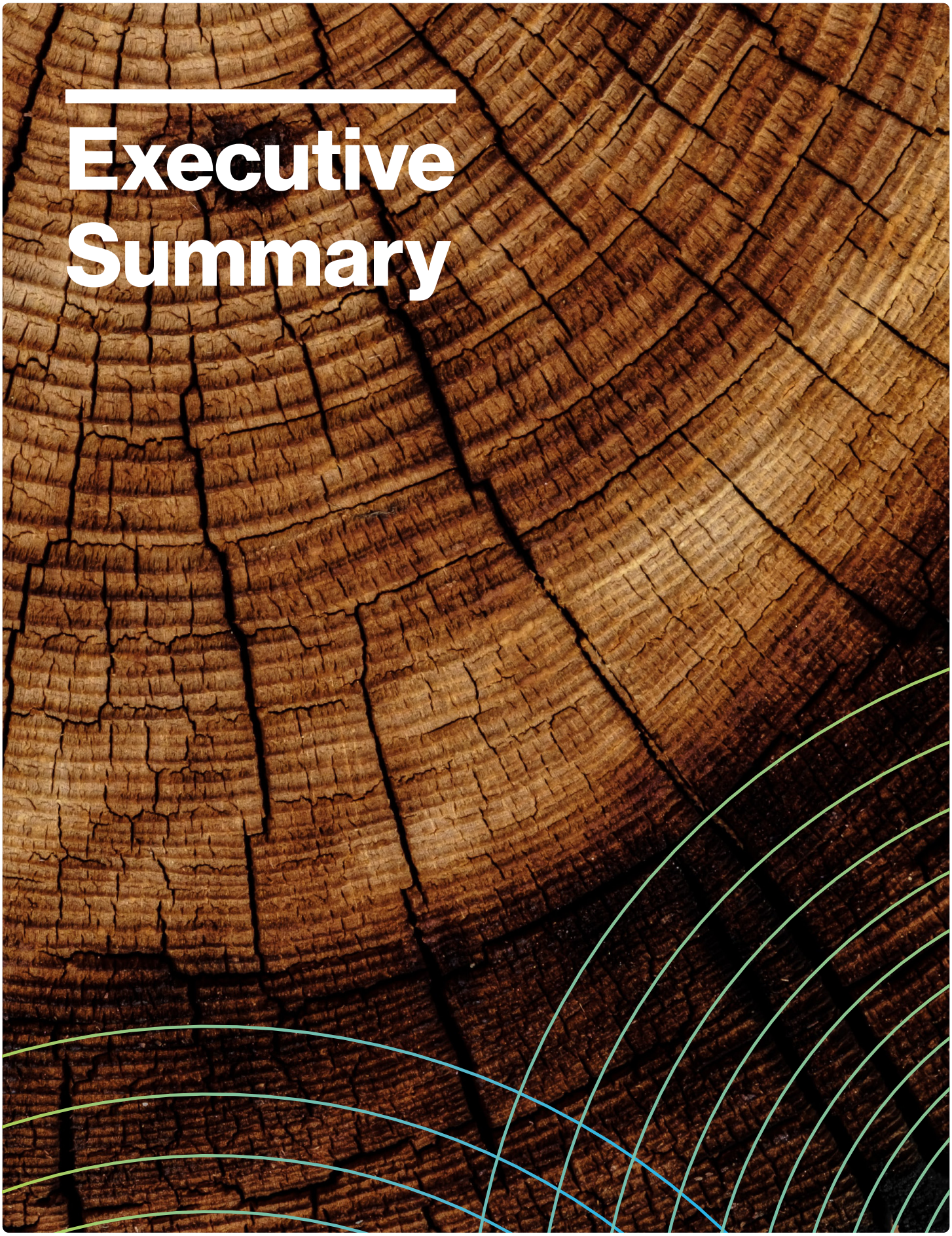
Executive Summary



Climate change is a threat to all life on Earth and greenhouse gas (GHG) emissions are the culprit. While governments have taken steps to mitigate the damage by cutting carbon emissions — and to adapt to unavoidable climate conditions — it will take further effort to head off the danger.

To give ourselves a chance at avoiding the worst effects, we need solutions to counteract current excess emissions and to compensate for future emissions. These solutions can be found in negative emission technologies (NETs), and there is no pathway that will get us to where we need to be without them. But to have enough NETs soon enough, British Columbia needs a strategy. There's no other path, and no other time to create a strategy but the present, if BC wants to not only survive climate change, but even thrive despite its challenges.

First, a definition: negative emissions is the removal of GHGs (mainly understood as CO_2) from our atmosphere to address climate change. There are various NET methods but what they all have in common is that they take carbon from the atmosphere and lock it away in long-term storage within vegetation, soils, rocks, geological reservoirs and more. Examples of NETs include:

- machines that remove CO_2 from the air and send it to storage;
- land management that increases the storage of carbon in plants and soils; and
- changing of ocean chemistry to indirectly draw down CO_2 from the air.

In British Columbia, we need a CO_2 removal strategy to guide how we approach innovation and build capacity across a variety of NET solutions. This report makes the argument why and articulates what it can mean to be strategic. Key elements, among others, include:

- **Adopting a co-production process that brings together policymakers, industry and more to build the sector.** The absence of an established sector and the complexity of NET further supports a proactive role for policymakers. A strategy should seek to combine the agility and ingenuity of the private sector with the long-term risk capacity of the public sector.
- **Growing the NET sector as an integrated whole, which means supporting a portfolio of solutions and the people behind them.** Near-term, the goal is to bring an effective NET sector into existence; long-term, it means ensuring the sector is sustainable.
- **Ensuring a strategy is adaptive so that it can work with uncertainty, risk and opportunity.** There must be a commitment to building both NET capacity and institutional knowledge. Enabling finance for first-of-a-kind, pilot and larger-scale initiatives can create positive learning-by-doing feedbacks — but only if our culture and processes are set up to accommodate it.

Negative emissions technologies are an irreplaceable part of effective climate action. BC needs to encourage innovation and build capacity — in a way that is sustainable for the long term. It is imperative that we launch a strategy building process to guide policymakers, industry and the public if we are to catch the escaping opportunity to limit the worst of climate change. This report is a both primer on how to do it and a call to action.

Key Takeaways

What are NETs, and why they are important?

- NETs are an essential component of meeting climate targets — reduced emissions aren't enough on their own.
- NETs are the only option to reverse GHG emissions.
- Diligence is required to ensure something is really a NET as deployed.
- BC needs a strategy for developing the NET sector.

The need, the opportunity and consequences

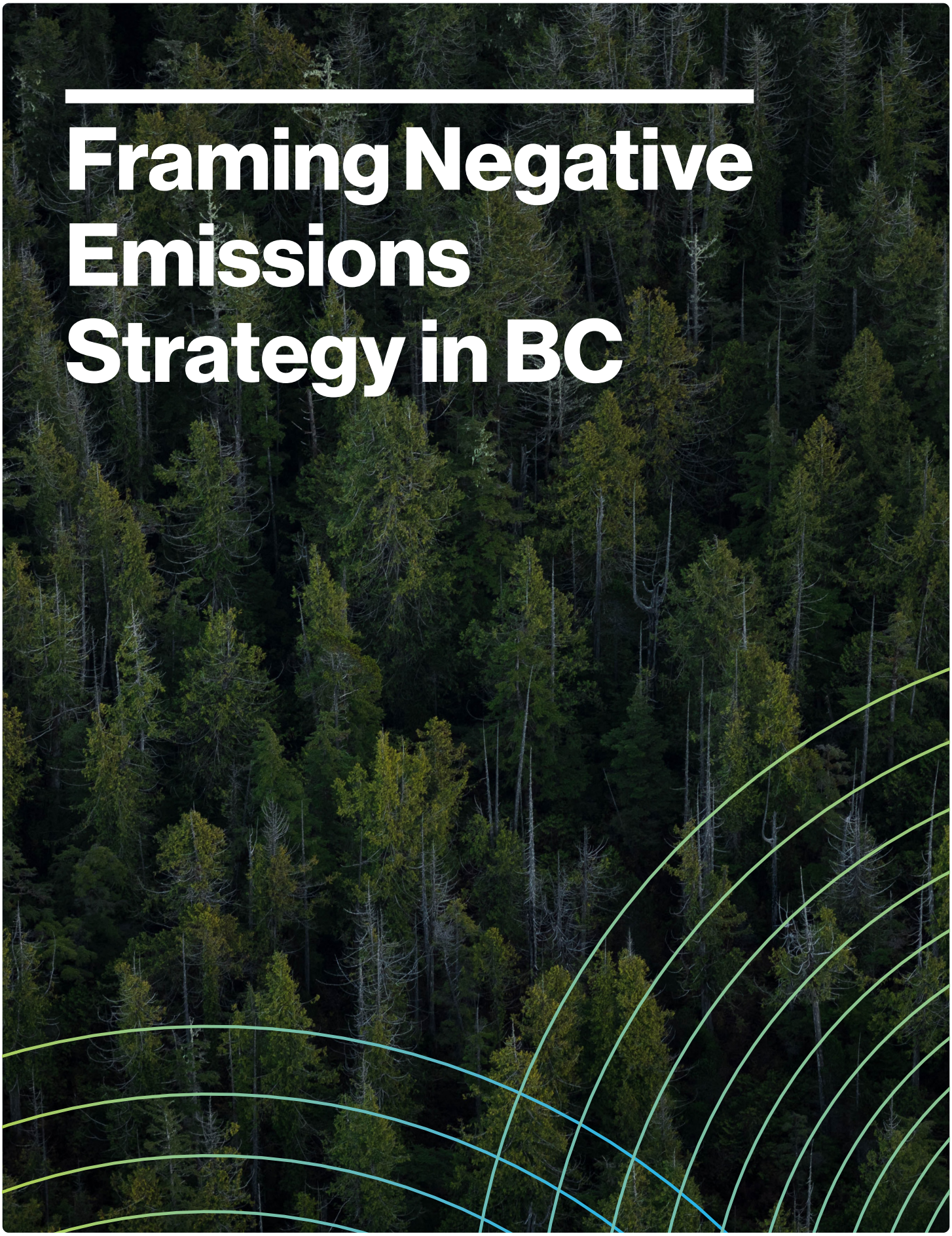
- A commitment to net-zero GHG emissions is also a commitment to NETs.
- NETs do not absolve us from pursuing drastic emissions reductions.
- When it comes to NETs, policymakers hold a key role towards an effective strategy.
- NETs can be motivated by responsibility and/or economic opportunity – and either way, we need capacity.
- We need to translate long-term confidence into near-term action.

Challenges and early warnings

- NETs are likely to be just as or more disruptive as other elements of a net-zero transition.
- NETs' character, timing and project-level circumstances have technical and governance implications.
- Current motives behind NETs might not be aligned with a sustainable future.
- A better, more coordinated research, development, demonstration and deployment (RDD&D) approach is recommended.

Building NET capacity

- Do not just build NETs, build the system – environment, relationships, processes, etc. – to build NETs.
- NETs are not displacing incumbents, yet established interests stand to win and lose. Those with foresight are seeking to shape NET solutions and policy to their advantage.
- Public-industry co-production might create better institutional capacity for NETs. Breaking down jurisdictional and disciplinary silos can help NETs benefit from existing expertise.
- Building the NET ecosystem means supporting the technologies and the actors pursuing them. Envisioning the future can inform proactive measures spanning early stages through large-scale deployment.
- NETs require deeper understanding of progress and potential. This may be achieved with technology-centric roadmaps reflecting technical, economic, supply chain, regulatory and further dimensions.
- Rethinking risk, opportunity and responsibility might reframe NETs as a climate change hedge, and not just a sectoral mitigation tool. The corollary is how risk and incentives may be redistributed to grow participation.
- NETs require working with uncertainty but urgency demands we avoid analysis paralysis. This might be overcome by placing value on learning and investing in learning.



Framing Negative Emissions Strategy in BC

What are NETs, and why they are important?

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- **BC needs a strategy for developing the NET sector.**

Climate change is an existential threat.
To have a chance at avoiding the worst of its effects, we need solutions to redress excess emissions and to compensate for future emissions beyond our direct control. We know what these solutions are — negative emission technologies — but to have enough, soon enough and on acceptable terms, British Columbia needs a strategy.

Negative emissions are the removal of greenhouse gases (GHGs) from our atmosphere to address climate change. Carbon dioxide (CO_2) is the usual target (i.e., carbon dioxide removal, or CDR) and it may be removed directly from the atmosphere or indirectly via the oceans. Where negative emissions are the goal, negative emissions technologies (NETs) are the means. To be a true NET there must be an additional and net-negative GHG outcome from a project-level lifecycle perspective. This is essential because different configurations of seemingly similar project and technology elements can result in different outcomes. It is important to always ask: Is this really a NET?

> *The challenge we face today is that NETs simply do not exist at climate-relevant scales – it is a sector that needs development. Yet given the urgency of climate change, we should also rethink how we approach development.*

This outcome-oriented definition of NETs deliberately captures the broadest set of possible solutions. These solutions are diverse and may be distinguished along several dimensions — abiotic or biogenic processes; energy, material, area, etc. costs; biophysical capacities; co-benefits and co-harms; carbon sequestration robustness; and more — all while recognizing that project and site-specific

> *For virtually all scenarios assessed by the IPCC, CDR [carbon dioxide removal] is necessary to reach both global net zero CO_2 and net zero GHG emissions, and to compensate for residual anthropogenic emissions.*
>
> **(Intergovernmental Panel on Climate Change, 2021)** [1]

considerations can upend typical expectations of a solution or solution-family.

The challenge we face today is that NETs simply do not exist at climate-relevant scales. It is a sector that needs development. Yet given the urgency of climate change, we must also rethink how we approach development.

Why should BC contemplate a NET/carbon removal strategy? BC has many features that are compatible with NETs: vast geographic area, productive ecosystems, renewable energy potentials, geology compatible with CO_2 sequestration and more. Extractive industries also figure prominently, including fossil energy, forestry and mining (the latter two are presently a GHG liability but could become a benefit). BC also presents a unique context: vast (but not empty) public lands and waters; wealth disparities and economic vulnerabilities across and within remote communities and regional hubs; increasing severity of climate change-related impacts (e.g., sea-level rise, forest fires, flood, drought) on coastal and inland communities, and on potential NET solutions; and scales where project-level influence can be, and is, exerted by provincial authorities.

A proactive, made-in-BC strategy may better reflect local priorities and context, and may forestall inevitable pressures by other jurisdictions lacking their own domestic NET capacity. In all, there is both challenging inertia behind business as usual and promise for sustainable transformation. In other words, BC could be a model for how to do NETs right.

This document proposes framing for a provincial strategy for NETs in BC. It is written as a primer for thought leaders and decision agents within governments and industry. It does not require prior familiarity with negative emissions, but an addendum of suggested resources is provided. The document is structured in three main parts:

1. What NETs are — why we need them, what makes them special and how our current path may pose problems.
2. An argument for building institutional capacity for NETs, and what characteristics that capacity may entail.
3. Guidance on strategy formulation, including sketches of potential vision, principles and policy elements.

You keep using that word...

If you follow NETs in the news, or in industry or scientific publications, you may have seen language like: **engineered, tech-based, land-based, natural or nature-based solutions (NBS)**. These terms are used to loosely describe complete NETs but generally derive from the mechanisms for carbon removal (e.g., photosynthesis or machines) or for carbon storage (e.g., within biomass or geological reservoirs). We caution that the engineered-versus-natural dichotomy can obscure realities of NET practices — for example, an NBS-framed NET could realistically cloak a monoculture forest plantation. This is likely a very engineered and activity-intensive operation, and is unlikely to align with people's preconceptions of "nature" or of a "forest." For another example, the language of "clean" within climate discourse may serve as a cloak for continued hydrocarbon dependence — and association with "engineered" NETs can be constructed to either vilify such NETs or to promote them within the "clean" narrative. Within this report, we sparingly invoke such terms to make technical distinctions (e.g., around capture or sequestration) or to mirror the language used in references. Overall, NET strategy formulation should contemplate all options yet understand the specifics of any solution and its fit within a milieu.

Some examples of NETs

Deep NET technical expertise is not essential to navigating this report. Nevertheless, we offer several suggestions of informative resources toward the end of the document. As well, the illustration below, while not exhaustive, highlights the breadth of proposed solutions. In comparing the different solutions, consider:

- **Where is the carbon originating?**
- **How is it captured?**
- **Where is it going?**
- **How permanent is that destination?**
- **How is it overall additional on a lifecycle basis?**

Similar questions are posed when evaluating whether something is, in fact, a NET. **For example, contrast carbon capture and sequestration (CCS) applied to a fossil fuel-powered facility versus direct air carbon capture.** Both capture systems output CO_2 and both streams may be sent to permanent geosequestration but only the direct air capture (DAC) system is a negative emission because its carbon was previously in the atmosphere. Another example: CO_2 from a DAC system may be directed to one of enhanced oil recovery (EOR) or to a non-hydrocarbon-affiliated reservoir; both streams of CO_2 may be permanently sequestered but the new fossil extraction induced by EOR works against that configuration's net negative quantity.

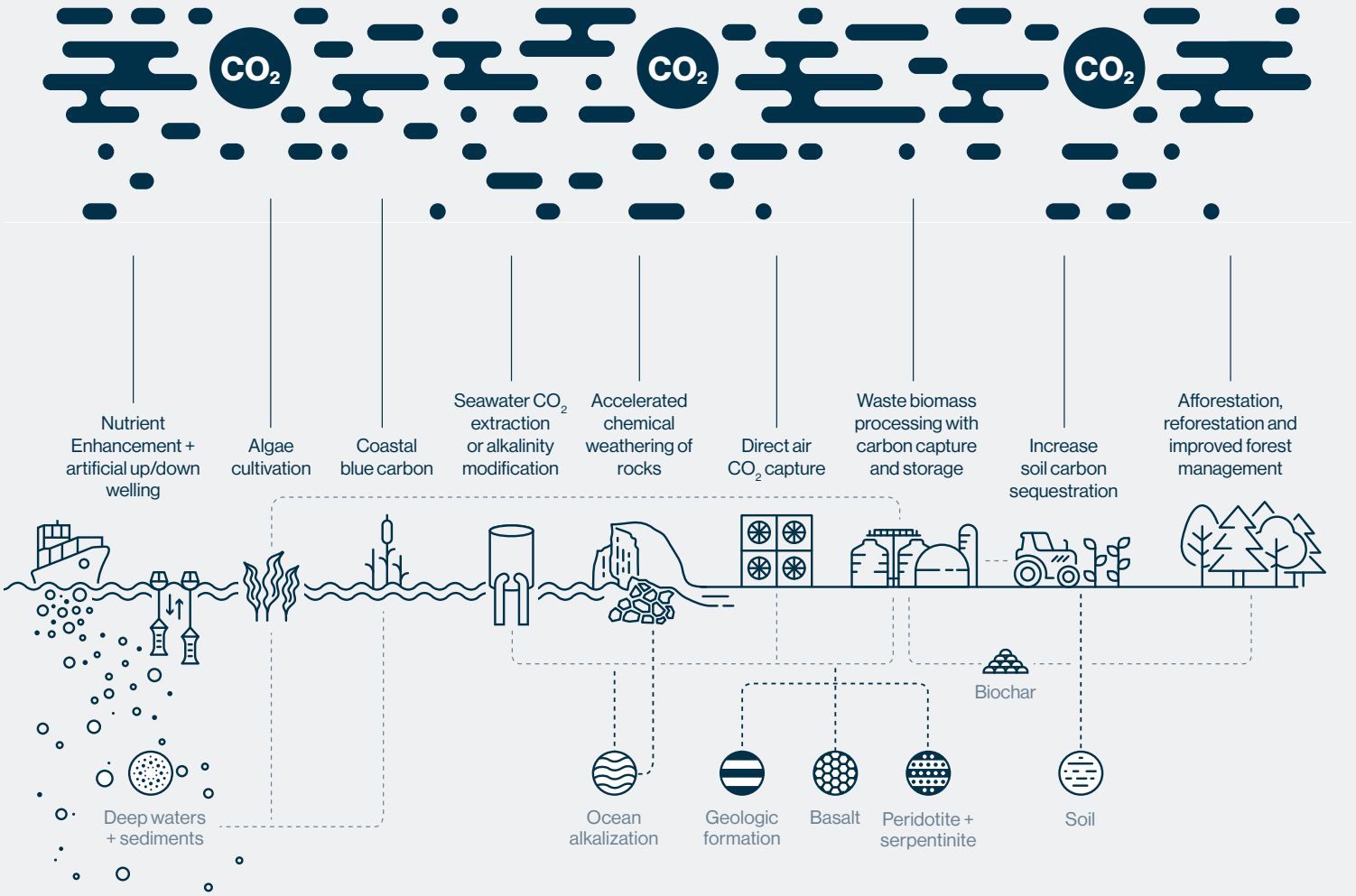

Illustration adapted from *CDR Primer*[2]

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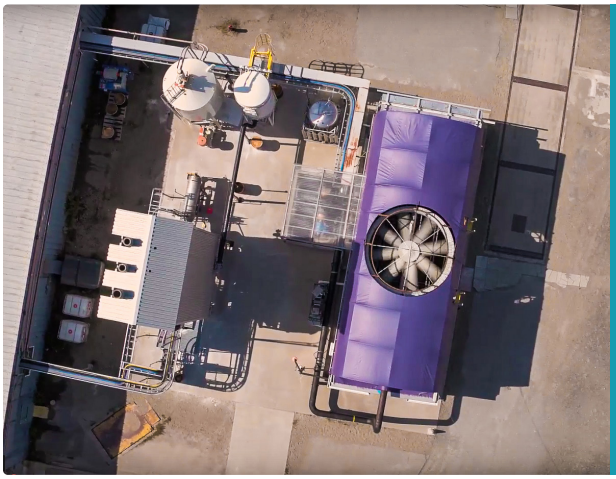
Examples of NET opportunities in BC

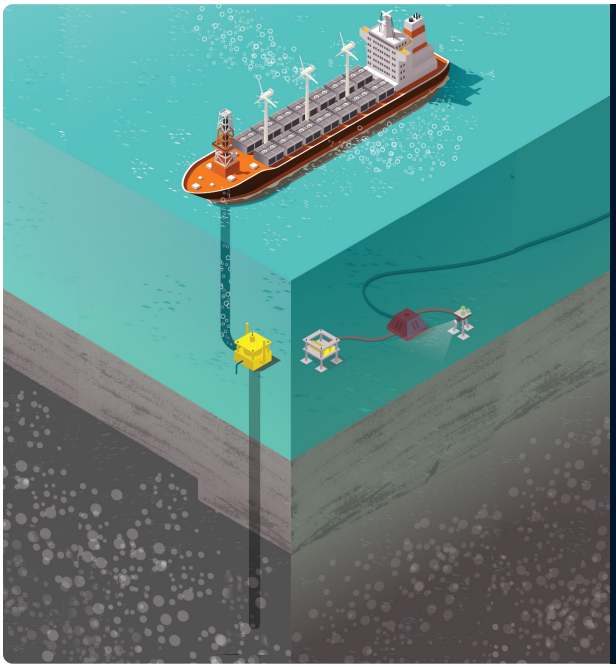


Carbon Engineering

Carbon Engineering is a global leader in CO2 Direct Air Capture (DAC) technology, headquartered in Squamish, BC. It captured CO2 from the air for the first time in 2015. The first large-scale commercial application to use Carbon Engineering's technology is being developed in partnership with subsidiaries of Occidental Petroleum for a Permian Basin (Texas) facility that will comprise some mix of enhanced oil recovery and pure geosequestration objectives. **carbonengineering.com**

CascadiaSeaweed

Cascadia Seaweed is a BC-based ocean seaweed cultivator. Its current focus is sustainable consumer packaged goods, however it is investigating the potential of reducing emissions by cultivating seaweed. The concept is that a portion of the photosynthetic carbon drawdown stimulated by farming may be stored within accumulating sediment deposits. Cascadia Seaweed is a member of the Oceans 2050's Seaweed Project, whose consortium of farmers is seeking to quantify the global carbon sequestration afforded by seaweed farms. **cascadiaseaweed.com**



SOLID CARBON

Solid Carbon is developing a NET with the distinction of using BC's vast subseafloor basalts for CO_2 geosequestration. Reactive mineral reservoirs (e.g., basalts) promise robust storage of CO_2 via transformation into carbonates (rock). The NET system is completed by DAC powered by renewable energy that is otherwise too remote for grid connection. The proposed Cascadia Basin site might also serve hard-to-abate point source carbon capture in southwestern BC. Solid Carbon is an awardee of the Pacific Institute for Climate Solutions' flagship Theme Partnership Program, and the team is now building further partnerships for its next step of a field demonstration. **solidcarbon.ca**

Image: Ocean Networks Canada

The need, the opportunity and the consequences

- **A commitment to net-zero GHG emissions is also a commitment to NETs.**
- **NETs do not absolve us from pursuing drastic emissions reductions.**
- **When it comes to NETs, policymakers hold a key role towards an effective strategy.**
- **NETs can be motivated by responsibility and/or economic opportunity – and either way, we need capacity.**
- **We need to translate long-term confidence into near-term action.**

Unwinding global warming and climate change requires achieving net-zero GHG emissions and sustaining net-negative emissions onwards. The "net" in net-zero implies some lingering hard- or slow-to-decarbonize positive emissions may be offset by NETs. However, NETs cannot circumvent our need to drastically reduce current positive emissions[1], or for investing towards adaptation and resilience. The more we delay mitigation today, the more NETs we need tomorrow. Leaders might only now be realizing that their commitments to net-zero GHGs are implicit commitments to NETs — exposing a knowledge gap around NETs' need, expressions, implications, limitations, potentials, etc.

The need is not just a number for future NET capacity (tonnes of carbon dioxide per year, or tCO_2/yr). "Just a number" presumes much for society, including: trajectories of positive and negative emissions; risk tolerance in meeting climate targets; choices of NETs; definition of our relationships with lands, waters and each other; and norms around equity. Simply meeting a target offers little confidence of success if underlying conditions are not aligned. It is essential to recognize how norms, biases and assumptions may be embedded within narratives and knowledge-products (e.g., the concept of a GHG budget, or integrated assessment modelling) relied upon in decision-making, even in those that are ostensibly apolitical. Our argument is that defining the NET need should reflect a multi-perspective and evolving vision of a sustainable transformation and future.

Nevertheless, a number might help policymakers[2] to begin understanding the scale of the problem — and mustering the resources to meet it.

- Globally, the National Academies citing IPCC results suggest we need CO_2 removal capacity of approximately 10 $GtCO_2/yr$ by 2050 and 20 $GtCO_2/yr$ by 2100 to meet the 1.5°C Paris goal [(3)].

[1] Reducing positive emissions is also known as abatement or (a more limiting case) decarbonization. Mitigation is also synonymous with reductions in the context of specific positive emissions. However, NETs can also be considered within mitigation in the context of overall GHG quantities.

[2] "Policymakers" is used herein to reflect that policy can come from any number of governments operating within BC's geography. Provincial government participation is key, but it does not need to be exclusive.

- For Canada, Pozo et al. inferred a singular cumulative global negative emissions requirement (687 $GtCO_2$ by 2100) from IPCC modelling of 1.5°C-compatible scenarios (348 to 1,218 $GtCO_2$ by 2100 range), and created possible national allocations based on several equity principles[4]. Therein, Canada's cumulative allocation ranged from a few to just under 20 $GtCO_2$ (0.28 to 19.53 $GtCO_2$ by 2100), i.e., a fractional per cent to a couple per cent of the global share.
- For BC, we produced provincial and territorial allocations based on several equity principles of a national 15 $GtCO_2$ by 2100 total. Our analysis suggested BC allocations of 0.63 to 2.17 $GtCO_2$ by 2100. We also produced a second, bottom-up estimate based on 2019 provincial emissions [5] that we anticipated to be hard-to-abate. This analysis suggested a BC need of 24,281 $ktCO_2eq/yr$ (about 35 per cent of 2019 total emissions of 68,629 $ktCO_2eq$).

A grim milestone looms to further underscore the urgency of the need. Less than a decade at current emission rates remains before the global 1.5°C budget is exceeded, beyond which any excess must be reversed with NETs — in other words, going beyond net-zero and well into net-negative to remediate emissions.

> *For Canada and BC, NETs could be an economic boon through export of negative emissions outcomes, as other jurisdictions may simply lack the domestic capacity to meet their NET goals.*

The economic possibilities

We have thus far framed NETs as a responsibility but, for Canada and BC, NETs could be an economic boon, through export of negative emissions outcomes (e.g., credits) as other jurisdictions that lack the domestic capacity to meet their NET goals could be compelled to import NET credits. Meanwhile, Canada has the biophysical resources for outsized NET development: land, water, energy (both renewable and fossil-fuelled), geosequestration potential and more.

Protestors attend a climate protest in Vancouver in 2015.

This turns the policymaker's problem upside-down. "How much do we need?" becomes "How much are we comfortable with?", because NETs will still come with local and wider co-benefits and co-harms. Thus, BC and Canada could invest in domestic needs and be confident of international market absorption of any excess, or we might be ambitious and invest to become the world leader of a sector with a guaranteed place in any net-zero world.

The negative emissions sector's market size is as yet uncertain. It relies on the global pace and determination to attain net-zero and/or some GHG budget. An indication may come from the extent of declared pledges to achieve net-zero by at least 2050. For example, the Net Zero Tracker compiles global net-zero pledges across governments and large corporations [6]. As of July 2022, country-level pledges cover 83 per cent of emissions, 91 per cent of GDP (PPP) and 80 per cent of population. Assuming we achieve 10 $GtCO_2/yr$ by 2050, and using the planned Canadian federal carbon price of C$170 per tonne CO_2 (thus far), a rough guess of the 2050 global negative emissions sector market size is C$1.7 trillion/yr.

For comparison, Canadian petroleum exports amounted to C$122 billion in 2019 (one fifth of all exports). Canada is the third largest oil exporter (eight per cent of a total 48.8 MMb/d in 2018, including oil, NGL and other) and is the sixth largest gas exporter (six per cent of a total 137.2 Bcf/d or 4 Bcm/d in 2019). Further, the global value of Canadian-owned energy — all energy, not just petroleum — assets

was C$685 billion in 2018 [7]. Similar to oil and gas, Canada is gifted with the resources compatible with NETs. Moreover, the established oil and gas technology and workforce are adaptable to some NET systems. Were Canada to make the investment and secure similar market share for NETs, it is conceivable that NETs could fill the economic gap left behind by oil and gas and support a just transition[3].

There is no substitute for negative emissions. We will be unable to limit climate change without enough NETs, with consequences for lives and livelihoods across the country. A jurisdiction without domestic NETs will be beholden to cross-border transfers and may face challenges around availability, cost, quality and ensuring fair sourcing. While NETs might be conveniently reduced to a dollar cost, they become exclusively a drag on domestic activity. Alternatively, a jurisdiction pursing domestic NETs naively will blunder into challenges that risk undermining their effort.

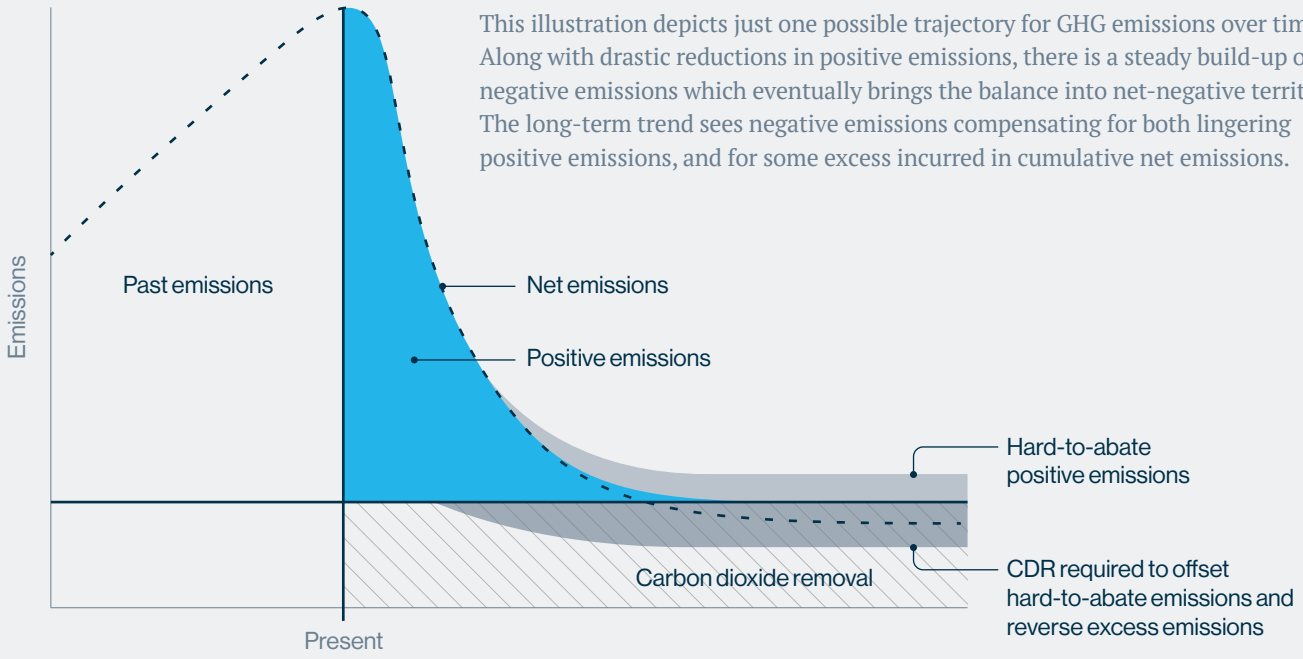
What might success look like? Success is meeting our GHG goals in alignment with broader vision and principles established within a strategy. When it comes to NETs, policymakers hold a key role towards an effective strategy. In their absence, signals originating from industry and the public are unlikely to secure a sufficient or suitable quality NET portfolio; rather, policymakers might hold the long-term vision and public interest while co-producing with industry to achieve better outcomes. Such production will need to encompass research, development, demonstration and deployment (RDD&D), with an eye to achieving scale. The policymaker may see little long-term risk in advancing NETs today but needs creative strategies to translate this long-term confidence into short-term-driven participant action.

This report proposes a framing for strategy development that is NET-specific and has a BC focus.

> *The negative emissions sector's market size is as yet uncertain. It relies on the global pace and determination to attain net-zero and/or some GHG budget. An indication may come from the extent of declared pledges to achieve net-zero by at least 2050.*

The relationship between positive, negative and net emissions

This illustration depicts just one possible trajectory for GHG emissions over time. Along with drastic reductions in positive emissions, there is a steady build-up of negative emissions which eventually brings the balance into net-negative territory. The long-term trend sees negative emissions compensating for both lingering positive emissions, and for some excess incurred in cumulative net emissions.



[3] Canadian Climate Institute modelling suggests a narrow path for oil and gas survival in its *Canada's Net Zero Future* report [8].

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What makes NETs different?

NETs provide a novel and unique service within society: GHG removal from the atmosphere. While we can infer lessons from other climate change mitigation and technology development precedents, NETs' distinguishing features may challenge our pre-existing patterns of innovation and development. We suggest a few cross-cutting features below, noting that different actors may hold different views on their relative importance.

From a GHG management perspective:

- NETs can be tackled at arbitrary scales, whereas abatement (reductions) scales are bound to consumption; i.e., NET targets can be chosen and grow with relative freedom, while abatement is framed around exhausting a given sector's potential. The corollary is that NETs require intervention ("do something") while abatement may be tackled through intervention or avoidance ("give up something").
- CO_2 removal from the atmosphere is fundamentally an energy and/or material expense, and absent a policy or market incentive, does not create immediate value for the NET practitioner. Although some NETs might claim economic side-streams that subsidize the effort, these may have limited capacity to scale.
- NETs can sever the relationship between GHG-emitting activities and action to directly abate those emissions. This is facilitated (if we allow it) by the generation, exchange and application of carbon removal credits, which offers arguably more credibility than credits based on avoided or reduced emissions. Unchecked, NETs (and promises thereof) permit temporal and spatial GHG redistribution, with potentially profound implications for the environment and justice.

Emissions reductions can't reverse a blown GHG budget.

Farmers using tractors and farm equipment to harvest crops in Victoria, BC.

From a new technology development and scaling perspective:

- The NET sector is starting from near zero but must grow rapidly. Delay compounds the challenge, with negative repercussions for failing to grow enough capacity, or the "right" capacity mix, fast enough.
- Policymakers control the demand-side for NETs. This can be direct (e.g., through procurement) or indirect (e.g., through GHG regulation). Volunteer demand is arguably insufficient and unreliable. However, negative emissions' climate benefits are immediately and globally socialized, and there is no physical product to handle.
- Potential NET solutions are diverse, but there are no substitutes for NETs: positive emissions reductions can't reverse a blown GHG budget. Meanwhile, NETs may carry uncertainties and be siloed within established sectors.

Overall, these features are just part of a bigger NET context. A NET strategy might seek to be adaptive to changing context and emerging feedbacks between policymakers, industry and the public. This is expanded upon in the next section exploring some the challenges and early warnings facing NETs.

Challenges and early warnings

- **NETs are likely to be just as or more disruptive as other elements of a net-zero transition.**
- **NETs' character, timing and project-level circumstances have technical and governance implications.**
- **Current motives behind NETs might not be aligned with a sustainable future.**
- **A better, more coordinated research, development, demonstration and deployment (RDD&D) approach is recommended.**

NETs face numerous challenges. Some are centred on the solutions, such as overcoming development barriers or knowledge gaps, while others arise from how NETs might disrupt existing relationships. All are important. The significance of any challenge may also depend on the choice of NET and the context of a specific project. The National Academies provide in-depth reviews of several NETs and have proposed research agendas to fill gaps [3, 9]. Within this section, we highlight a few examples of what we consider crosscutting NET challenges:

- **Scale and resource competition**

  NETs are needed at massive scale and urgently, and a robust plan would even include a surplus of capacity in case some mitigation and NET solutions do not meet expectations. This demands a massive system for building and operating NET capacity. Resource-wise, we need to plan for and supply components, consumables, infrastructure, etc. This includes those that may be renewable (e.g., energy, biomass) and those that are finite (e.g., land). As NETs scale, they may face competition in mustering these resources, and risk competing with other GHG-reduction or -adaptation efforts.

- **Execution barriers spanning early development through diffusion**

  Siloed efforts, laggard investment and current incentive structures risk delaying RDD&D and shaping unfavourable long-term NET portfolios. In early development stages, typical investment expects their return-on-investment within a few years; this can discourage bolder long-term NET development. Moreover, a high-risk/high-reward environment (with few and outsized winners) may be incompatible with diversified NET portfolios and may create barriers to research and entrepreneurship. Nearing commercial

stage, projects may be unfinanceable because of longer-term economic and/or regulatory uncertainty, even if the unit economics may be acceptable at inception. Timescales and uncertainty might also favour NETs with smaller capital expenditure and shorter economic lives, which could affect profitability, efficacy or other values.

> Inertia behind business as usual

NET adoption might be perceived as a fix to avoid disruption of current GHG-intensive practices and/or losses on pre-existing investments. Note that exposure is not limited to corporations as public funds – through investment funds or pensions – may also be exposed to losses. The risk is that establishment commercial interests target NETs for subjugation and set them up to fail. This is illustrated in a few hypothetical examples: some stakeholders within agriculture and forestry might seek NET credits from practices with questionable additionality (i.e., are near business as usual) and distort financial incentives across the broader NET sector; other stakeholders might seek exemptions from pollution regulation, including hard-to-abate sectors whose activities must be correlated to NET deployments; and yet other stakeholders might argue future NETs promise more cost-effective GHG outcomes versus near-term action.

> Governance

The public perspective on NETs is relatively uncharted. Meanwhile, the NET legal and regulatory space is emergent while also facing obstacles of amending existing rules. Three examples of contentious issues follow:

1. Navigating moral hazard, an example of which is NETs enabling shifting risk and responsibility over time, i.e., delaying action today and risking saddling future generations with intractable atmospheric GHG levels and/or a suite of insufficient NET solutions. In the near term, the impacts of climate change are asymmetrically distributed across the globe and socioeconomic circumstances.

2. Navigating outcomes at the project level, where a risk is that well-resourced NET proponents may exploit communities that may be economically vulnerable or face other unmet needs. The related risk for proponents is that failing communities may incite public obstruction leading to delay or abandonment of projects.

All solutions have their challenges. A sign warns of high voltage at a German electricity installation.

3. Navigating how we account GHGs, where removals are distinct from avoided emissions, and NETs can be distinct amongst one another. The commonplace reduction to mere net CO_2 flux betrays a false equivalency assumed across solutions.

The above challenges are interconnected and may reinforce one another. Already, we can identify cause for concern with contemporary approaches relating to NETs, as incentives might not support outcomes compatible with long-term sustainability.

> *Already, we can identify cause for concern with contemporary approaches... instead of long-term sustainability, we risk selecting for lowest cost, attractive short-term cashflows.*

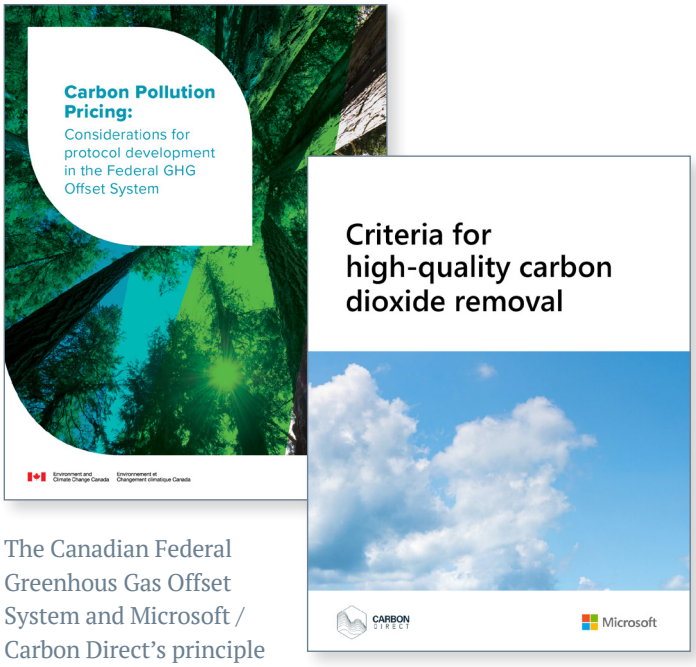
As example, consider BC achieving a sufficient and robust NET portfolio. Enough CO_2 must be removed from the atmosphere — and kept removed — over indefinite timescales, regardless of any project or technology-level failures in removal efficacy, variation in sequestration capacities or longevities, exogeneous climate change impacts, and more. Instead of long-term sustainability, we risk selecting for lowest cost, attractive short-term cashflows and only superficial meeting of GHG targets.

- The Canadian Federal Greenhouse Gas Offset System requires monitoring and reporting of only 100 years for projects involving biological sequestration (e.g., via modified agricultural or forestry practices) [10]. Such NETs generally have a low cost per tonne of CO_2. This disadvantages NETs involving geological sequestration (>10,000-year typical timescales and typically higher costs per tonne CO_2) seeking to serve the same compliance system.
- Microsoft is a corporate leader, seeking carbon removals to be carbon negative by 2030 and reversing the equivalent of its historical emissions by 2050. Together with Carbon Direct, it produced a principles document [11] with broad NET applicability that acknowledges the importance of sequestration durability and risk. Nevertheless, the outcomes of early corporate purchases [12] was more than 1.3 million tCO_2 where >99 per cent have sequestration terms of ≤100 years, which is acknowledged as needing improvement.

For these examples, land area constraints and ~100-year turnover might challenge future sustainability if other approaches have not been concurrently and adequately developed. It is not that such biogenic NET approaches are inherently bad; rather, it is an issue of how we incorporate them within our plans.

In another few examples, consider achieving a NET sector consistent with ideals of good governance. NETs must be socially sustainable well over 100-year timescales, as abandonment or neglect risks foregoing ongoing carbon removals and/or reversing past removals, undermining climate goals. At present, the NET sector is a relative free-for-all and/or an accessory to other climate policy, and is threatened with being financialized for private profit and/or for hedging of climate change liabilities.

- The Canadian federal 2 Billion Trees Commitment [13] declares carbon capture as a main priority. However, the credulously presented connection between number of trees planted and carbon capture may contribute to public misconceptions of the capacities of forest-related and other biogenic NETs. There is unfortunately little discourse on the long-term storage or on the trees' milieu that impact effectiveness. The same can be said for the implications of non-CO_2 GHG and non-GHG climate effects.



The Canadian Federal Greenhous Gas Offset System and Microsoft / Carbon Direct's principle document.

- The US federal 45Q tax credit incentivizes industrial point source carbon capture but also direct air capture. The concern is that it subsidizes fossil energy proponents at the expense of arguably more sustainable decarbonization efforts, leaving NETs and carbon capture from hard-to-abate point sources in the policy debate crossfire. A lack of mandatory public disclosure [14] compounds problems.
- Oil and gas companies are prioritizing nature-based solutions to generate carbon credits destined for offsetting operations and even selling to consumers. Oxfam considered the net-zero targets of Shell, TotalEnergies, Eni and BP, estimating that their plans may require 50,362,000 to 69,400,000 hectares of land – and if all oil and gas followed their leadership, 500 million hectares — about half the size of the US [15]. In this scenario, private interests are deciding that scarce nature-based potential is to be spent on prolonging a mostly business as usual, GHG-emitting energy system while concurrently initiating a land rush that risks disrupting local social and environmental relationships.
- The case of the California Air Resources Board cap-and-trade system and its forest-based credits provides an example of how actors may seek to game the design of a GHG program. Here, the preferential selection of stands

for credit generating projects combined with crediting benchmarked against coarse regional averages enabled systemic over-crediting [16].

For these examples, public perception of motives and efficacy risk eroding confidence that NETs are being pursued in the public's best interest. A negative public perception of NETs cast during this formative period may become hard to shed. As the technical and social landscape continues to unfold, policies need to adapt.

Overall, we have had decades of warning on the consequences of GHG emissions — and decades of failure to meet emissions reduction targets. It is unquestionable that we need to do better when it comes to addressing positive emissions and their underlying drivers. When it comes to NETs, we cannot afford to repeat a pattern of indecisiveness. We should take stock of what has previously or continues to work and fail, and apply it to a new NET objective.

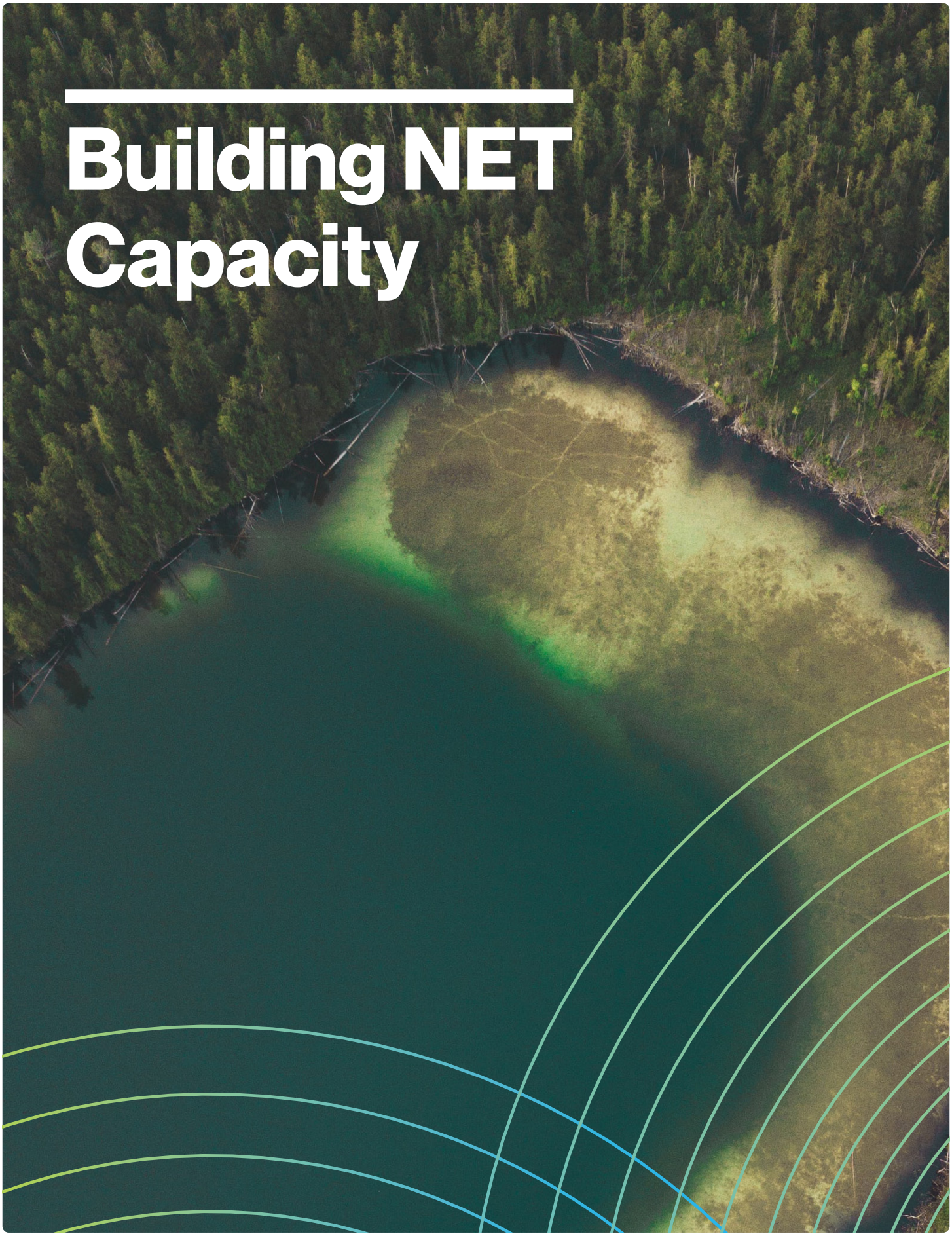
Shopify and Stripe (Frontier) take a different approach

The e-commerce company **Shopify** and the payment processing platform **Stripe** are corporate leaders seeking to mitigate their and their clients' GHG impact through carbon removals. Their efforts make a miniscule dent in gigatonne global problem but it can be a lesson for the policy action we ultimately need. Originally, Shopify and Stripe adopted parallel strategies that were arguably more impact-oriented than those of their peers. The companies sought to exclusively support drawdowns with sequestration at any price per tonne CO_2, with a minimum annual dollar amount of total pledges. In April 2022, they joined forces together with Alphabet, Meta and McKinsey Sustainability to form Frontier, an advance market commitment to buy an initial US$925 million (C$1.279 billion) of negative emissions by 2030 featuring permanent (>1,000 year) sequestration. The aim is to fill the gap in early-stage support of such NETs so that we have viable options in the future. By defining an investment pledge and de-emphasizing precise pricing and quantity for what is still a novel practice with room to improve, Frontier can consider impact more holistically.

Overview of how Frontier works *(Illustrative only)*

Frontier stripe Alphabet shopify Meta McKinsey & Company

Building NET Capacity



How we get there

This report has so far framed NETs and argued a need for innovating in how we approach them. This section proposes steps toward delivering on that innovation, organized into three concepts: a catalytic community; a mobilization; and an entrepreneurial ethos. This NET capacity can then work together with the development of a NET strategy.

Our proposal draws on the ideas of Victor, Geels and Sharpe, and Meadowcroft [17, 18] on transition toward a low-carbon/net-zero world — some of which have already inspired BC's most recent climate plan update *CleanBC: Roadmap to 2030* [19], which comprises a limited first treatment of NETs by the province. This section also draws on the ideas of Allan et al. on how Canada can position itself economically in a net-zero world. In particular, those ideas developed in partnership by the Smart Prosperity Institute, the Pacific Institute for Climate Solutions (PICS) and the Transition Accelerator [20], that emphasize a long-term strategic vision and co-development of industrial strategy by innovation clusters. The perspective taken within this report, however, does have a distinction from those listed above. This report presumes NETs will be developed within the province, but does not presume what motivates that development (such as an export profit motive). Thus, building NET capacity may grapple with the motives of individual actors, but it still needs a strategic-level answer to this key question: Why build NETs?

In part, this brief responds to Geels et al.'s "*Organising institutions for success: The most urgent priority*" as drivers of coordinated actions in sectors or systems. Notwithstanding the original context was international cooperation, the same may apply to domestic action. Domestic policymakers must ultimately drive NET demand on behalf of the public interest, either through market-based or other mechanisms[4].

As BC is a nexus of the resources and expertise applicable to NETs, it could also seek to lead internationally. This report

Premier John Horgan announces the *CleanBC Roadmap to 2030*. (Mike McArthur/CBC)

similarly responds to *CleanBC: Roadmap to 2030*'s stated needs for NETs. The caveat is that, regrettably, the roadmap narrowly defined its NET pathway as encompassing only engineered solutions, leaving other solutions fragmented across other sectors. This was seemingly picked up by engagement feedback to "develop a policy framework including a clear definition of NETs" and could be ameliorated in future *CleanBC* iterations.

> *Domestic policymakers must ultimately drive NET demand on behalf of the public interest, either through market-based or other mechanisms.*

The NET sector is emergent, making institution-building particularly challenging but also affording opportunities. Many approaches drawing on many knowledge domains may deliver the common negative-emission outcome but with different qualities and consequences. This is compounded by the uncertainty in how it all might fit into our future systems.

[4] This report hopes to make room for non-market-based approaches within NET discourse. Readers may notice that we avoid defaulting to "credits" as the measure of negative emissions outcomes.

Here we highlight three interrelated concepts for the actors and processes that might advance a successful NET strategy. Together with earlier NET framing, these ideas are reflected in later sections conceptualizing some of a strategy itself.

- **Do not just build NETs, build the system – environment, relationships, processes, etc. – to build NETs.**
- **NETs are not displacing incumbents, yet established interests stand to win and lose. Those with foresight are seeking to shape NET solutions and policy to their advantage.**
- **Public-industry co-production might create better institutional capacity for NETs. Breaking down jurisdictional and disciplinary silos can help NETs benefit from existing expertise.**
- **Building the NET ecosystem means supporting the technologies and the actors pursuing them. Envisioning the future can inform proactive measures spanning early stages through large-scale deployment.**
- **NETs require deeper understanding of progress and potential. This may be achieved with technology-centric roadmaps reflecting technical, economic, supply chain, regulatory and further dimensions.**
- **Rethinking risk, opportunity and responsibility might reframe NETs as a climate change hedge, and not just a sectoral mitigation tool. The corollary is how risk and incentives may be redistributed to grow participation.**
- **NETs require working with uncertainty but urgency demands we avoid analysis paralysis. This might be overcome by placing value on learning and investing in learning.**

"Alongside the policy actions for decarbonisation, a strategic commitment to institution-building is, therefore, the single most important activity that can be undertaken by any government wishing to lead the global response to climate change."

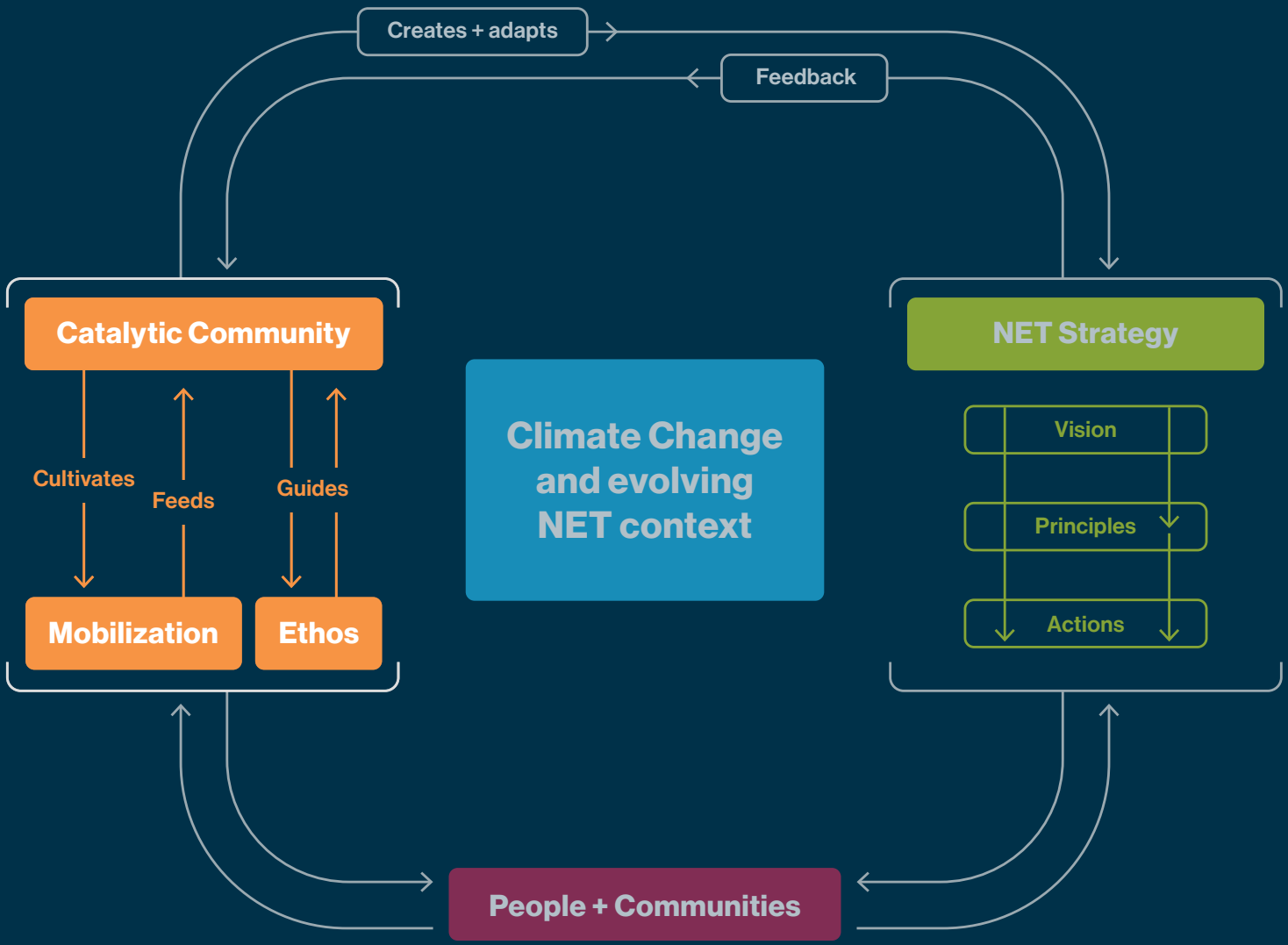
(Geels et al., 2019).

"Putting a transition approach into practice means accelerating system- or sector-level change to deliver net-zero and other societal benefits rather than just trying to secure the lowest cost incremental GHG reductions by a specified date."

(Meadowcroft, J. and contributors, 2021).

"To support the scale-up of NETs by 2030, B.C. needs an enabling environment that supports innovation, incentivizes public-private involvement and is flexible enough to adapt to change. That could include a supportive regulatory and policy climate, economic incentives, measures to reduce costs or new business models to achieve economies of scale."

(CleanBC: Roadmap to 2030)


Creates + adapts
Feedback
Catalytic Community
NET Strategy
Cultivates
Feeds
Guides
Climate Change and evolving NET context
Vision
Principles
Actions
Mobilization
Ethos
People + Communities

PICS

A catalytic community

A catalytic community forms the membership of an institution which can drive progress on NETs. As a start, this comprises those organizations, policymakers, and public and private leaders key to NET strategy development. Catalytic in this case means to emphasize those entities with the outsized capacity, potential or responsibility to build the future of NETs.

We envision co-production by public and industry participants, where public policymakers serve the crucial role of custodian of a NET strategy and the public interest. The importance of policymaker guidance cannot be overstated. As argued earlier, voluntary or indirectly instigated via GHG regulation, actions originating from industry or the general public are unlikely to secure a sufficient or quality NET portfolio. Moreover, on the longer horizon, depending on how fast positive emissions are reduced near-term policymakers may find themselves alone to subsidize NETs as contemporaneous polluters might not cope with legacy GHG emissions [21]. Similar to climate change adaptation, NETs demand pro-action, which is differentiated from other sectors serving immediate end users.

In addition to policymakers, the catalytic community's composition should represent the complete space needed to realize a NET sector. There must be a shared interest in the success of the sector at-large and include (at least):

- NET solutions and prospective solutions, expected to span a range of development stages;
- complete value chains (e.g., technology, materials, energy) and infrastructure integral to NETs and that may overlap with other sectors; and
- public and private finance, supporting initial concepts through to sustainable, large-scale deployment.

This report postpones suggesting how to best organize the community, noting that unresolved framings of NETs (e.g., as public versus private good) may influence the best approach.

Nonetheless, the general topic is touched on within the PICS and partners report Canada's Future in a Net-Zero World: Securing Canada's Place in the Global Green Economy [20].

On September 8, 2021, Climeworks launched Orca, the world's largest direct air capture and storage plant, making carbon dioxide removal on large-scale a reality. (Image: Climeworks)

> *The conventional wisdom amongst many policy-makers in Canada is that while governments have a role to play to support innovation, they should steer clear of "picking winners" and allow the marketplace to determine the pace and scale of deployment. The transition and energy system approach adopted in this report suggests a different view. History shows governments cannot avoid taking decisions about large-scale technological options – without such commitments in the past, we would not have built a national highway system and provincial electricity grids, nor developed nuclear power or the oilsands.*
>
> **(Meadowcroft, J. and contributors, 2021).**

Therein, a recommendation is to build on the information-sharing spirit of Canada's Economic Strategy Tables and Global Innovation Clusters by creating new, nimble and permanent institutions – a model of which is the public-private partnership (InnoEnergy) underpinning the European Commission's hydrogen strategy and battery alliance.

A challenge is developing proponents where coverage across solution-classes may be limited. While some types of NETs may benefit from high-profile leaders (e.g., in the direct air capture, or DAC, space), others may be without clear champions. Compounding the challenge is representing next-generation improvement and novel concept as they emerge and face incumbents. This might be overcome by developing an iterative perspective based on NETs solution-classes, and creating an environment for building and attracting expertise (see next two sections). Given a general class of NET, developing associated supply chains and infrastructure is essential to growth and may create synergies and/or conflict with other priorities. For example, NETs that manage concentrated CO_2 streams (e.g., DAC or bioenergy with carbon capture and storage, or BECCS) share solutions (e.g., sorbent expertise, logistics, sequestration) with those of abatement-focused carbon capture and sequestration (CCS). Note that even without fossil energy, we will still face process emissions from industry that may benefit from widespread CCS adoption.

Consequently, strategies for industry (such as those being developed by NRCan [22]) should contemplate NETs within their vision and planning. Biogenic NETs may similarly draw from adjacent sectors (e.g., forestry, agriculture and mariculture) and share common supply chain components (e.g., biogeoclimatic zone-matched seedling stocks, precision agriculture technologies, nutrients, water, land, etc.). In BC, there may also be a role for other sectors with stakes in NETs, for example oil and gas, emissions-intensive and trade-exposed, and others deemed hard-to-abate. These might have economic significance to the province; expertise or practices adaptable to NETs; and/or an imperative to identify a net-zero pathway.

Coproduction of a NET strategy demands willingness from all participants to invest in relationship building and to depart from a slower policy iteration model characterized by ad hoc consultations, policy roll-out and a typical two-year lag on observing any GHG outcomes. It also demands effort toward dismantling intra-governmental barriers as NETs — technologies, resources, needs, etc. — span multiple provincial and federal ministry mandates and legal frameworks. Siloed policy development within energy systems, forestry and land-use, carbon pricing, just transition, innovation and more is unlikely to deliver a coherent NET plan; rather, a coordinated and adequately empowered policymaker cadre is more likely to maintain the integrity of a NET strategy.

European Commission President Ursula von der Leyen announced a plan for an EU-wide hydrogen alliance initiative on March 10, 2020. (Source: EC - Audiovisual Service)

A further element of this co-production model is bolstering the independent analysis capacity of policymakers. This might be developed internally and/or by engaging communities of independent experts. Independent capacity avoids over-reliance on industry expertise, which may mitigate risks of lost knowhow (e.g., due to ephemeral industry participants and priorities), and of policy capture by private interests that can be amplified within public-private partnership models.

Assembling a NET community is just one part of building capacity. Due to uncertainty in how NETs and other elements of a net-zero world will unfold, the parallel task is designing it to be self-sustaining and relevant over the long-term. This is the focus of the next two concepts.

A mobilization

A mobilization convenes the catalytic community and sustains its membership and the solutions it produces. The objective is to motivate new ideas to support continued development and experimentation, and streamline integration into the NET sector.

Geels et al. describe sectors as progressing through stages of transition: emergence, diffusion and reconfiguration. These reflect the general types of activities occurring around a new innovation. Inspired by the former, *CleanBC: Roadmap to 2030* describes NETs as progressing through stages of market readiness: emergent, early deployment, deployment and maturity. These reflect policymakers' measure of NETs against market-readiness indicators encompassing extent of adoption, anticipated implementation costs, workforce readiness and co-benefits potential. We suggest some adjustments to build upon these framings, with an emphasis on working all stages in support of both the sector and its constituent solutions.

Geels and *CleanBC* frame transition as occurring within an existing environment, i.e., Geels' multi-level perspective on sustainability transitions: landscape, regime and niches. This environment mediates how new ideas go from obscurity to ubiquity, generally starting from niches. For NETs, an omnipresent landscape feature is the need to address climate change and the resultant need for negative emissions.

However, there are arguably no significant NET niches or an active regime, as NETs do not offer a direct value to end users (in contrast to, for example, serving mobility or energy needs). Niches that do exist might not be aligned with desirable long-term NET solutions and/or may be the result of — or of speculation on — limited policy (see Challenges and early warnings). Meanwhile, the regime offers no NET incumbent to challenge, consequently established systems may be relatively malleable in how they respond to NETs' emergence. In short, NETs may demand more pro-action than other elements of a sustainable transition but also afford us greater creative opportunity.

This report and other works often simplify NETs as "new" but this is not entirely true. What can be overlooked is

An aerial view of Crofton Mill, a pulp and paper mill located in the Vancouver Island town of Crofton, British Columbia.

a distinction between and nuance within technological and market readiness. For example, there are decades of experience in managing forest ecosystems for carbon outcomes (just not necessarily removals) and in the logistics of CO_2 (e.g., for enhanced oil recovery). There are also now DAC machines that extract CO_2 from the atmosphere operating in the kilotonne range and being engineered for megatonnes [23, 24].

Meanwhile, forestry-related and other biogenic negative emissions are being traded on small voluntary markets while DAC faces challenging financing. Yet, biogenic approaches might still benefit from research-oriented modelling, mapping and longitudinal study whereas DAC-based NETs might benefit more from deployment-oriented operating experience and economies of scale. Generalizing, the perceived novelty of NETs is couched within an underdeveloped market whose lens obscures what is already technologically feasible today — and likely economically-feasible in a net-zero future with developed policy.

In truth, NETs benefit from an established body of know-how, some of which is already NET-focused, the rest awaiting to be oriented towards NET goals. However, progress and potential are obscured if evaluations of the technical dimension are misunderstood to measure the whole and/or are overly reductive. An example of this pitfall is overly simplified application of technology readiness levels (TRLs). The nature (i.e., the whole of technical, economic, regulatory,

social, etc.) and significance of the effort needed to advance through a given TRL can be expected to vary with the choice of NET; meanwhile, the reduction to a one-dimensional scale may not register concurrent (including second- or later-generation) developments across different subsystems or scales. The takeaway is that an effective mobilization must pursue a deep understanding of NETs' state of the art, so supports can be targeted effectively and that we understand our progress toward a NET vision.

This report envisions the mobilization as a coherent system of supports coproduced by the catalytic community to advance NETs at the scales of the sector, technology classes and individual proponents, and where support is concurrent across all stages of sector development. Concurrency is a key element, and refers to supporting a NET where it is and where it needs to be. An example of concurrency is *CleanBC: Roadmap to 2030*'s suggestion to invest in research, development and deployment while also building an accounting framework for NETs. We argue greater commitment is warranted, especially for proactively designing NET systems.

The reason is two-fold: we have unique certainty on the need for NETs, and NETs already occupy the expanse of readiness, perhaps waiting for the right enabling policy. Our foresight on demand-side need can even extend to the role of different classes of NETs. For example, based on Canadian Climate Institute modelling (8), we might anticipate a key role for biogenic NETs but also uncertain sufficiency, and therefore justify also laying groundwork for more abiotic NETs for the long-term.

Coherency refers to the real actors that need to come together to make NETs happen and their differentiated needs as they progress through RDD&D. This is not afforded by the current pattern of one-off investments. Pursuing NET leadership also means facing Canada's chronic failure in innovation: while our academic research performance is relatively strong, we fail at translating this into economic productivity [25]. Here, we highlight two interrelated considerations pertinent to NETs: fragmentation and the demand side. Over an RDD&D path, NET proponents face public support that is fragmented across different initiatives of different levels of government and ministries; and while full RDD&D "coverage" might be claimed, this can miss the

This report envisions the mobilization as a coherent system of supports coproduced by the catalytic community to advance NETs at the scales of the sector, technology classes and individual proponents, and where support is concurrent across all stages of sector development.

continuity between programs; i.e., the alignment of program goals and intake criteria with those preceding/following or any bigger picture.

Moreover, ad hoc and narrowly-mandated initiatives may block some solutions outright or create delay as mandates may slowly evolve. This fragmented public support for innovation may be interpreted as an outcome of a branch-plant economy: we are proficient at incremental improvements to systems but are neglectful of the full value chain and especially the demand side. Apathy on our part risks any novel NET investments to being poached by or made subservient to foreign machinery. Recommendations include emphasizing the demand-side and commercialization [25, 26], and again aligning around a firm policy commitment to a NET vision.

The last element of co-production by a catalytic community affords the expertise and real-time experience of participants, alongside policymaker analysis capacity building. When it comes to designing supports, this may yield better prioritization of both cross-cutting and targeted NET initiatives, and justification for more adaptable public agency mandates with greater discretion for catalyzing innovation.

Summarizing, we suggest conceptualizing and kickstarting a critical mass of the entire NET sector. This may generate self-reinforcing positive feedback, as described by Geels et al., albeit without having to wait out a transition to diffusion phase. We have intentionally avoided prescribing policy mechanisms in this section, focusing instead on desired effect; rather, we believe mechanisms may best emerge as a product of the catalytic community and strategy — if provided a third concept, an entrepreneurial ethos, is adopted to cut through chaff and uncertainty in pursuit of the big picture.

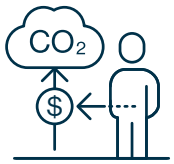
Malleable responses

We invite readers to imagine how organizations might reorient in response to a couple of not-unlikely policy scenarios:

1. an increasing GHG tax with NET offsetting permitted;
2. a bounty on GHG removals; or
3. a takeback obligation imposed on fossil energy producers.

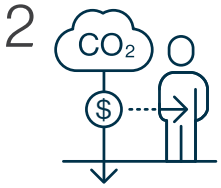
These policies may create different opportunities and align regime forces differently. What might be the impacts beyond NETs? Who is positioned to profit and to lose? How might emissions-intensive sectors (e.g., oil and gas, or O&G) in particular profit or lose – and react? To what extent are overall GHG or NET outcomes guaranteed? Which NETs might attract greater direct support or discover more supportive adjoining systems?

Here are some speculative outcomes:

1 

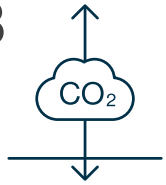
Increasing GHG tax:

NETs face a cost barrier driven by reductions. Up to the point marginal reductions costs escalate enough, NETs go nowhere, and then are still only feasible at the marginal intervention price. This assumes the GHG tax is set high enough to even allow for NETs; it could be too low and polluters may simply opt to pay the penalty. There is no cap on ongoing emissions. For NETs, pricing may have to escalate unpalatably high. Considering how industries can often command exemptions, the costs may be disproportionally borne by a vulnerable public lacking means to decarbonize. Early NET winners will be those with lower up-front and operating costs (i.e., biogenic approaches with relatively less-robust sequestration and land-rush risks) while other solutions will have delayed development. Forestry and agriculture sectors are positioned to capitalize early, for instance, yet have their own issues with sustainability.

2 

Bounty on GHG removals:

NETs have defined revenue but the price has to be sufficient for proponents. Solutions with better ROI might attract more investment but even more costly options can still be pursued profitably. Larger quantities of deployment are expected and higher capital investments are feasible with long-term price certainty. Oil and gas (O&G) are well positioned to profit from developing NET projects, which could result in subsidizing business as usual. The public might not tolerate a perception of those who created the problem, being paid for providing the remedy. Without accompanying positive emissions limits, NET demand is prolonged and capacity risks being overwhelmed.

3 

Takeback obligation:

Emissions are, in theory, capped as any new emissions must be reversed. The price of emissions is linked to marginal removal costs, not merely abatement. There is an immediate NET cost and an incentive to reduce obligations by pursuing further mitigation efforts. Emissions-intensive actors will rush to secure NET futures. Nevertheless, fuel-centric O&G is likely moribund and will resist this scenario because it may quickly exhaust sufficiently low-cost NETs. Nimble O&G entities could still pivot into new NET and/or renewable energy entities. As other sectors, such as agriculture, might also face infeasible obligations without subsidies or exemptions, the public's influence upon winners and losers will become stronger and more explicit.

An entrepreneurial ethos

An entrepreneurial ethos guides the catalytic community in how it manages a mobilization and pursues a vision. The motivation is to avoid investments into further incrementalism, which has characterized our current, inadequate approach to climate solutions. NETs are potentially both disruptive and anti-disruptive innovation, having an uncharted capacity to motivate change or unduly sustain sectors with GHG liabilities, and can generally alter the imperatives for GHG reductions and climate adaptation. An entrepreneurial approach reflects where disruption often originates. Key themes for NETs comprise recalibrating our perceptions of risk and opportunity, navigating uncertainty and investing into learning and iteration. These are all linked but emphasize different parts.

NETs challenge us to manage downside potentials while assuming enough strategic risk/opportunity to achieve our climate goals. **Risk-averse investment that is limited to sure bets will not significantly contribute to learning nor will it accelerate deployments.** Furthermore, NETs require the contributions of many actors, so how and what they perceive as risk is critical to their participation. Stakes are elevated versus other development activities because of the urgency and scale of need, coupled with uncertainties around how solutions may perform at-scale.

It will not be enough for just policymakers to be confident in the future. Risks/opportunities exist at the strategic level, in addition to those deeper into policy initiatives, NET portfolios, NET classes and individual projects. At the highest level, NETs are the only means to reverse GHG budget excesses and can be a hedge against failing to mitigate positive emissions. Meanwhile at lower levels, specific technology or project investments have uncertain outcomes yet setbacks are integral to learning. A NET strategy might contemplate reconfiguring the who and how by which risk and reward are distributed to achieve sufficiently bold action while avoiding undue vilification of potential solutions or undermining public credibility.

Fruit stand and farmers market in Keremeos, BC, in 2021.

This report argues for urgent action on climate and NETs. Taking no action or deferring action on NETs are themselves strategic decisions and do not diminish the stakes. These decisions can be an outcome of misapplication of the precautionary principle, where the consequences of the do-nothing counterfactual scenario have been neglected. In other words, wait-and-see is a bet that others might advance NETs at their cost, but where we also jeopardize our capacity to sustainably meet climate targets, and where we forgo potential domestic and international leadership on how NETs are developed. It is a bad bet to take. However, because wait-and-see may prompt little action or scrutiny, it risks being the default of those who favour political expediency and business as usual. More generally, we warn how strategic ignorance risks undermining efforts on NETs.

Uncertainty surrounds NETs and navigating that uncertainty is essential to progress. Uncertainty can arise within many contexts: e.g., NETs classes and projects; the transition and systems of a 1.5°C-compatible world; NETs' fit into such a world; and more. Just a few examples include:

- uncertain negative emission effectiveness, e.g., within accumulation and stability of carbon in ecosystems; cost/energy/capture performance and embodied emissions

[5] McGoey offers a definition: *the mobilization of the unknowns in a situation in order to command resources, deny liability in the aftermath of disaster, and to assert expert control in the face of both foreseeable unpredictable outcomes* [27].

of built infrastructure; direct and indirect GHGs from land-use change or marketed products; and baselines for additionality more generally;

- uncertain and unintended consequences of large-scale deployment, which risk impacts to the environment and livelihoods;
- uncertain economic or technical feasibility from the proponent perspective, risking wait-and-see delay or withholding of pursuit; and
- uncertain effectiveness of policy actions towards desired outcomes.

NET solutions or their components may be at different stages of development and may draw support from different disciplines with adaptable bodies of knowledge. This suggests driving innovation and reducing uncertainty across solutions might benefit from granular indicators of status and differentiated support mechanisms (see A mobilization). Building confidence in NETs will take time and a willingness to experiment, building knowledge from real projects at increasingly larger scales. Meanwhile, the window is narrowing to act in time to be relevant within 2030 and 2050 pathways.

Navigating uncertainty necessitates implementing a learning process and institutionalizing its outcomes. This is partly addressed by coproduction by a catalytic community, and is furthered by seeking a process that is iterative and adaptable to changing contexts. An example model is the OODA loop (a cycle of observe–orient–decide–act) [28]. The steps are self-explanatory, but OODA features several useful concepts: feedback at all stages to restart or adjust responsively; observation of unfolding circumstances originating outside the process; and an explicit orientation component to make sense of observations through multiple lenses. Developing means for orientation is essential for navigating NETs — and is effectively a meta goal of this report.

Summarizing, an entrepreneurial ethos can help envision what NETs could be and inform some of the principles to get there. How this can be expressed within a strategy and policy actions is illustrated in subsequent sections.

NETs present an opportunity to achieve better outcomes with concurrent improvement in how we approach innovation. Equally, NETs can be a model for how we approach building other components of a green transformation. The suggestion here is for public-industry co-production to pursue learning-by-doing and become empowered to make bold yet justifiable bets. The further necessity is for this to work toward a clear objective — a long-term vision of sustainable NETs, encompassing how they are built, governed and reflect public priorities.

> *A clean competitiveness roadmap is a strategic collaboration between experts, industry, finance and governments at various levels. Its power lies in the connections, commitments and coordination that emerge from true collaboration across parts of society. This kind of roadmap is as much about the process behind as it is the content it contains.*
>
> **(Allan et al., 2022)**

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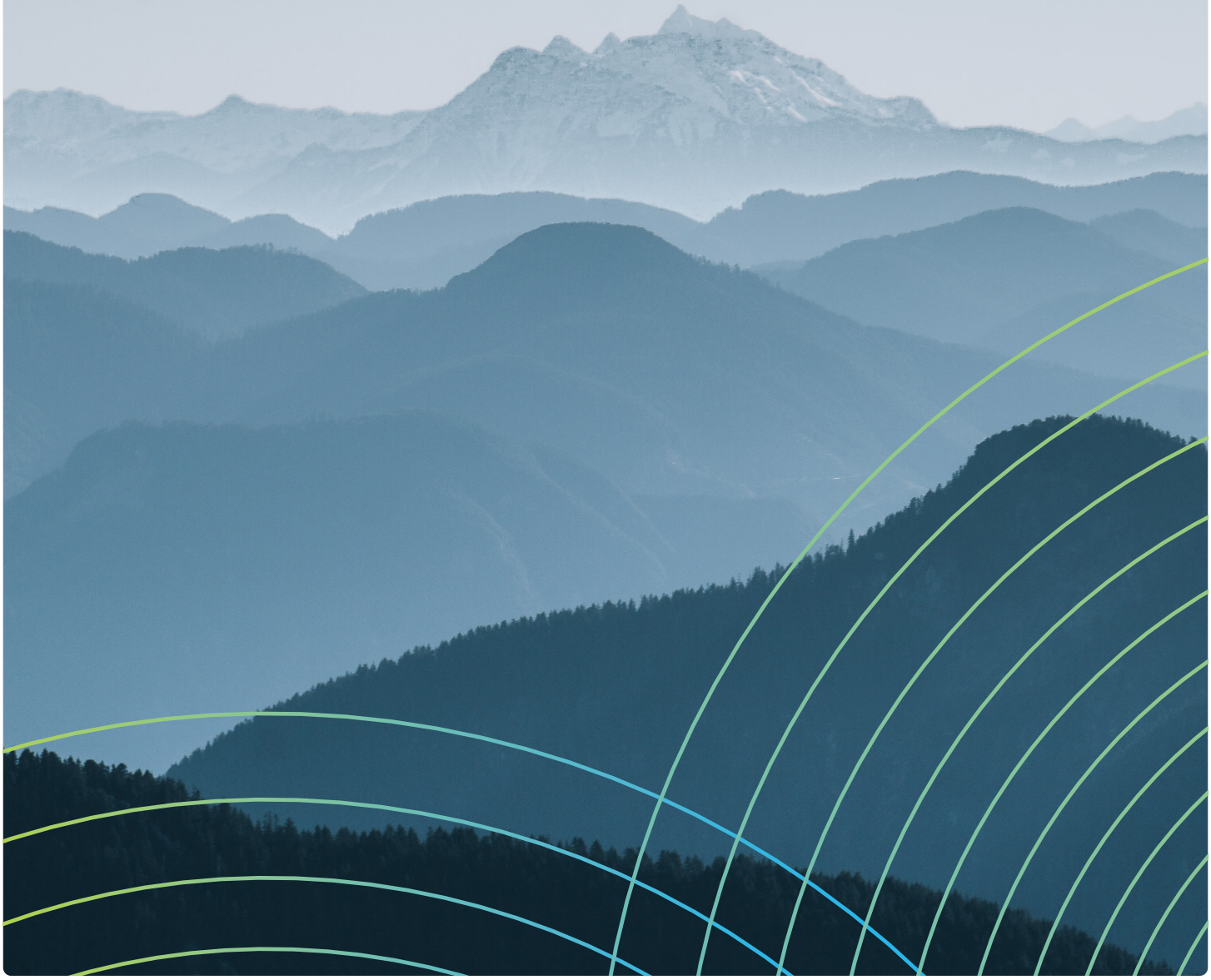
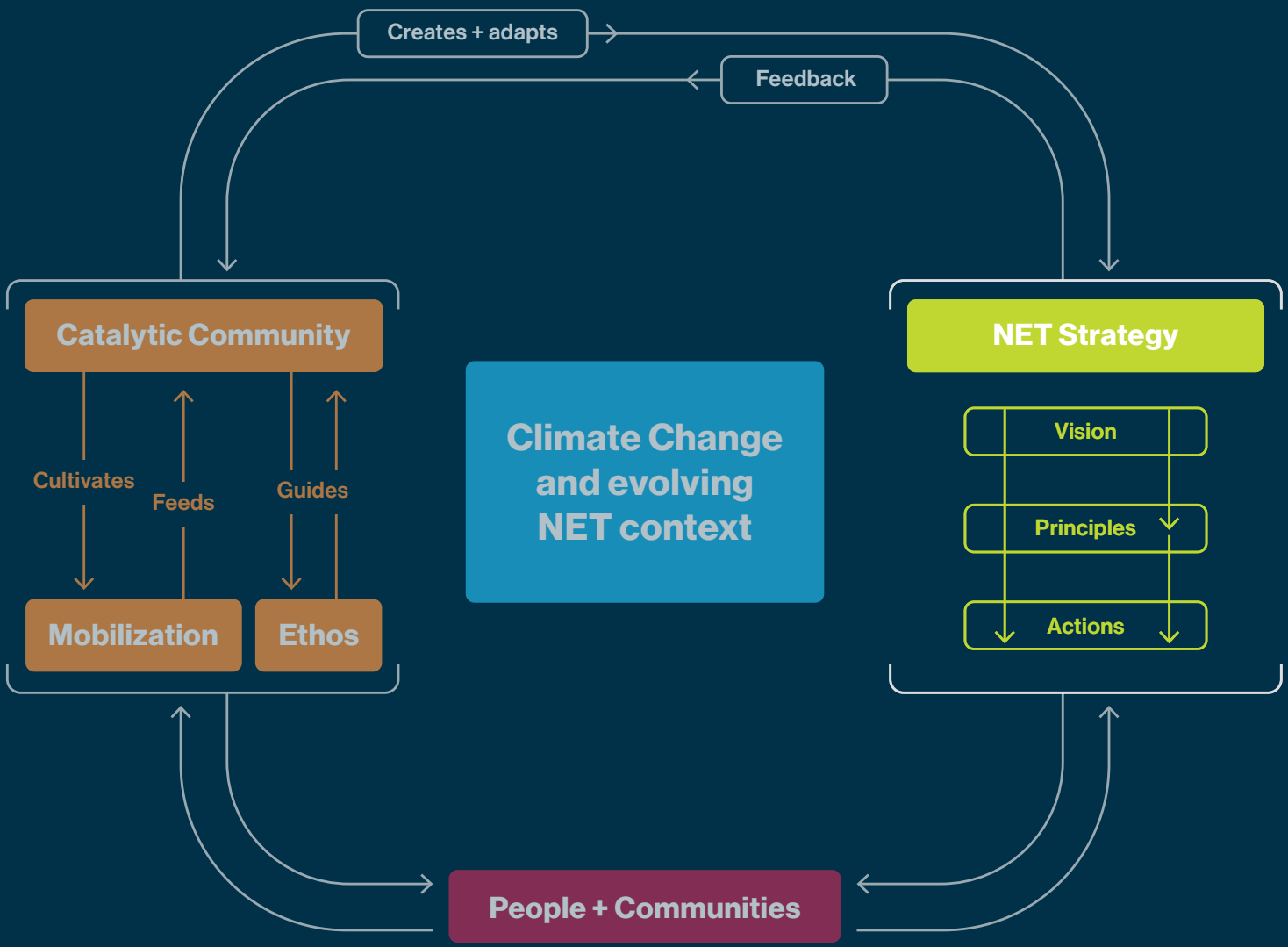
What Follows: Conceptualizing a NET Strategy



Having framed NETs and how we might approach NET innovation, the next sections shift to guidance on strategy formulation. We explore a vision for NETs, principles by which to operate, and some policy considerations. The goal is to develop the solutions space that responds to the unique circumstances facing NETs. It is not to advance a particular strategy, suite of policies or selection of NETs. We approach this with an intent to shift current conversation towards a broad, proactive perspective — broad, in that the starting point is solution-agnostic, and proactive, in that significant NET needs can be reasonably anticipated and pursued now.



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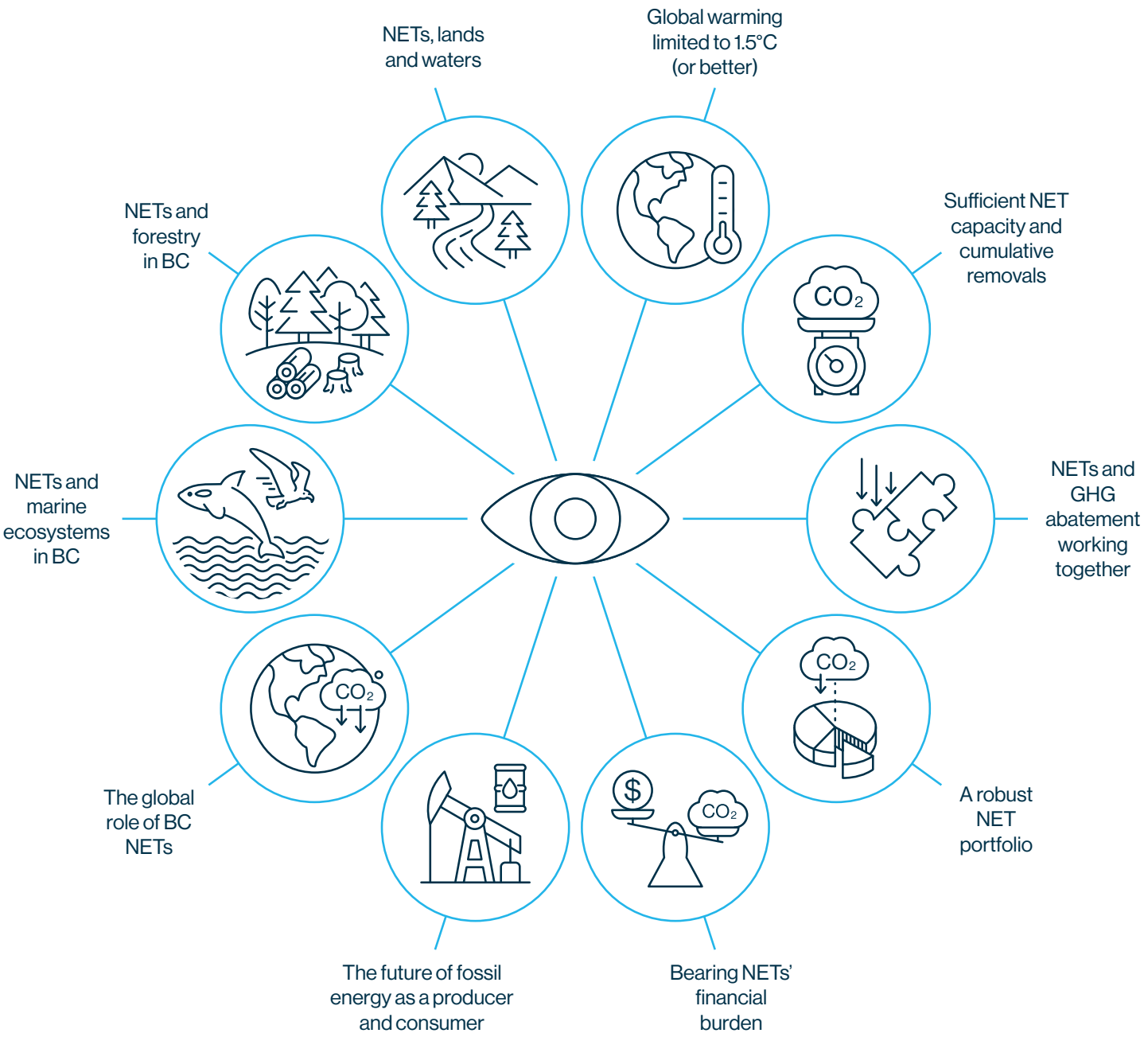
A vision for NETs

A vision codifies our future expectations for NETs and the highest-level goals of a strategy. Together with a set of principles, these are drawn upon when developing specific policy initiatives. Both are linked to NET capacity building described earlier, but also situate within a larger context of climate change, other governments' strategies and the public will for action. Continuing our proposed coproduction approach, a vision should inform the design of the innovation community and, in turn, reflect the insights afforded by the community.



BC has the opportunity to establish itself as a leader with an ambitious vision for NETs. It needs to be ambitious because achieving net-negative GHGs demands urgent and substantial NET capacity as well as transformative change within existing systems. An analogy: we must build a NET sector within a few decades roughly equivalent to the industries that created the problem over the span of a century and more. A vision must also be compelling[6], so that it can align our energy towards big-picture outcomes while also conveying purpose to the actions taken in the near-term.

At present, BC does not have an articulated vision for NETs. This section responds to this gap by advancing several elements to consider that touch on climate, the energy system, land and water stewardship, and NETs themselves. This breadth reflects how NETs are interconnected with many aspects of society. An effective vision will seek to draw NETs out of individual sectoral silos, clarify overall goals and forestall counterproductive feedbacks.

The original *CleanBC* plan [30] offers arguably limited direction[7]. Beyond a GHG target, *CleanBC* suggests improvements to: *Make life more affordable, healthier and more comfortable while creating a stronger economy and good jobs for the people of this province*, which are then translated to sectoral actions. Here, the incremental framing leaves an unsatisfying impression of what the future is and fails to deliberate how we should get there. Instead, actions are based on accelerating existing trends without necessarily addressing the bigger picture. Continuing this pattern may be problematic when it comes to NETs (see Challenges and early warnings). We might ask whether our trajectory is favourable, before putting more inertia behind it. This concern is exemplified by the near-term actions proposed for NETs in the *CleanBC: Roadmap to 2030* update, comprising *considering NETs as compliance pathways for the Low Carbon Fuel Standard (LCFS); building an accounting framework for NETs; and investing in research, development and deployment.* At face value, these may seem benign exploratory actions but they risk triggering some of the challenges and feedbacks articulated earlier.

In particular, linking NETs to fossil energy consumption (the LCFS) stumbles into moral hazard with implied positions on the relationships between decarbonization versus GHG reductions versus NETs, and who pays for interventions. We caution how short-sighted measures risk poisoning public acceptance for NETs.

> *We must build a NET sector within a few decades roughly equivalent to the industries that created the problem.*

A vision for a sustainable future is essential. Adopting a 2050 milestone and working backwards, we might anticipate conditions supporting success and build on them early. While 2050 might appear to be an abstract idea, it's not – ecosystem-based NETs may take decades to achieve peak productivity whereas built NET facilities may have multi-year development periods and multi-decade lifetimes. Our proposal for a "backcasting" approach contrasts the usual forecasting perspective typically limited to 2050 or intermediate horizons. Forecasting may not necessarily capture how society's systems are positioned for sustainability beyond projection periods, and as it derives from current NET foundations, it might also reinforce an incremental and constrained solution space — potentially risking the quality and timeliness of sufficient NET capacity. Starting from a vision and working backwards might create opportunity to incorporate broader perspectives and build public alignment earlier; identify actions that could be tackled proactively; and justify more transformative policy.

What follows is a sketch of possible elements comprising a NET vision. Each includes the element, a rationale and examples. We propose it as a minimum to build from, and we acknowledge how visioning is normative, making no assertion that what is listed is complete or "correct." Ultimately, an effective vision should draw upon a sustained and comprehensive public dialogue.

[6] This idea is exemplified by Collins' Big Hairy Audacious Goals (BHAGs). *The best BHAGs require both building for the long term AND exuding a relentless sense of urgency: What do we need to do today, with monomaniacal focus, and tomorrow, and the next day, to defy the probabilities and ultimately achieve our BHAG?* [29]

[7] This contrasts with BC's *Climate Preparedness and Adaptation Strategy* which presents a vision and guiding principles at the forefront [31].

Element	Rationale	Examples
 **Global warming limited to 1.5°C (or better)**	This is the root motivation for addressing GHG emissions. Limiting global warming is a stronger goal than simply achieving net-zero GHG emissions by 2050, that can otherwise obscure the nuance in budgets and pathways. Limiting global warming also highlights NETs' unique potential to redress historical emissions.	> BC's outsized leadership on NETs is generating significant global progress on limiting global warming.
 **Sufficient NET capacity and cumulative removals**	A minimum capacity must be sustained to offset hard-to-abate emissions and achieve net-zero GHGs. Cumulative removals address NETs' contribution to the GHG budget. These translate to climate stabilization and ultimate impacts. Quantities may reflect a domestic obligation or a relative global capability.	> BC is fully decarbonized, with the balance of positive emissions more than offset by NETs. > Having achieved net-zero, BC aims to reverse some quantity of its historical emissions.
 **A robust NET portfolio**	Quantities and composition of NETs should reflect uncertainty in expected capacity and sequestration integrity. Uncertainty may arise within R&D, projects as conceived, and as operating projects may be impacted by changing climate or human action. Robustness may entail a NET portfolio with a surplus of diversified capacity, and the flexibility to reorganize capacity — all to accommodate unforeseen circumstances.	> BC maintains a surplus of operating and queued projects. Any outcomes applied against legislated targets or regulatory compliance are backed up by an insurance pool. > NETs projects and innovation are incentivized not only by the lowest unit cost but, also, by the capacity and robustness they may add to the sector.

Element	Rationale	Examples
 **NETs and GHG abatement working together**	The practicalities of negative emissions and positive emissions reductions are different, yet their trajectories must achieve overall GHG targets together. Reasonable NET capacity risks being overwhelmed without sufficient reductions in positive emissions. Conversely, NETs risk cannibalizing the resources (e.g., land, electricity) needed to achieve those reductions. How is the relationship mediated when both streams warrant incentive?	> Developing distinct interim targets for negative emissions and emissions reductions, BC achieves net-zero emissions well before 2050, mostly through emissions reductions. > Comprehensive, long-range resource planning anticipates the burdens of negative emissions and emissions-reductions initiatives, but also the relief afforded by behavioural change and service delivery efficiency.
 **Bearing NETs' financial burden**	NETs will incur costs to develop and maintain capacity. Yet in a decarbonized world, there may be too little contemporaneous polluter capacity to pay. The gap may arise from legacy emissions exceeding allowed GHG budgets; subsidized ongoing emissions (e.g., agriculture may warrant exemptions to maintain food access); and further ongoing emissions without a proximate party (e.g., climate change-induced ecosystem degradation). Who will be accountable — and how?	> Future NETs are funded, in part, from a time-bound carbon-takeback obligation imposed on all emitters, having launched well before 2050. > In conjunction with oversight over the few remaining anthropogenic emitters, negative emissions have been reframed as a public good and are pursued by government procurement to redress historical and ongoing emissions.
 **The future of fossil energy as a producer and consumer**	Whether and how fossil resources meet energy and product needs weighs on NET quantities. Any unabated production and end-use positive emissions require concomitant negative emissions. Yet some NETs can be optionally powered by fossil energy. Meanwhile as a producer and exporter (where use emissions are then unattributed to us), we must reckon with continuing to profit from extraction while simultaneously seeking to advance the NET solution.	> BC's fossil energy sector is wound down as it is overtaken — competitively or via government mandate — by sustainable alternatives. > Production and consumption of BC's fossil energy are GHG-neutral through obligate point-source carbon capture and/or negative emissions.

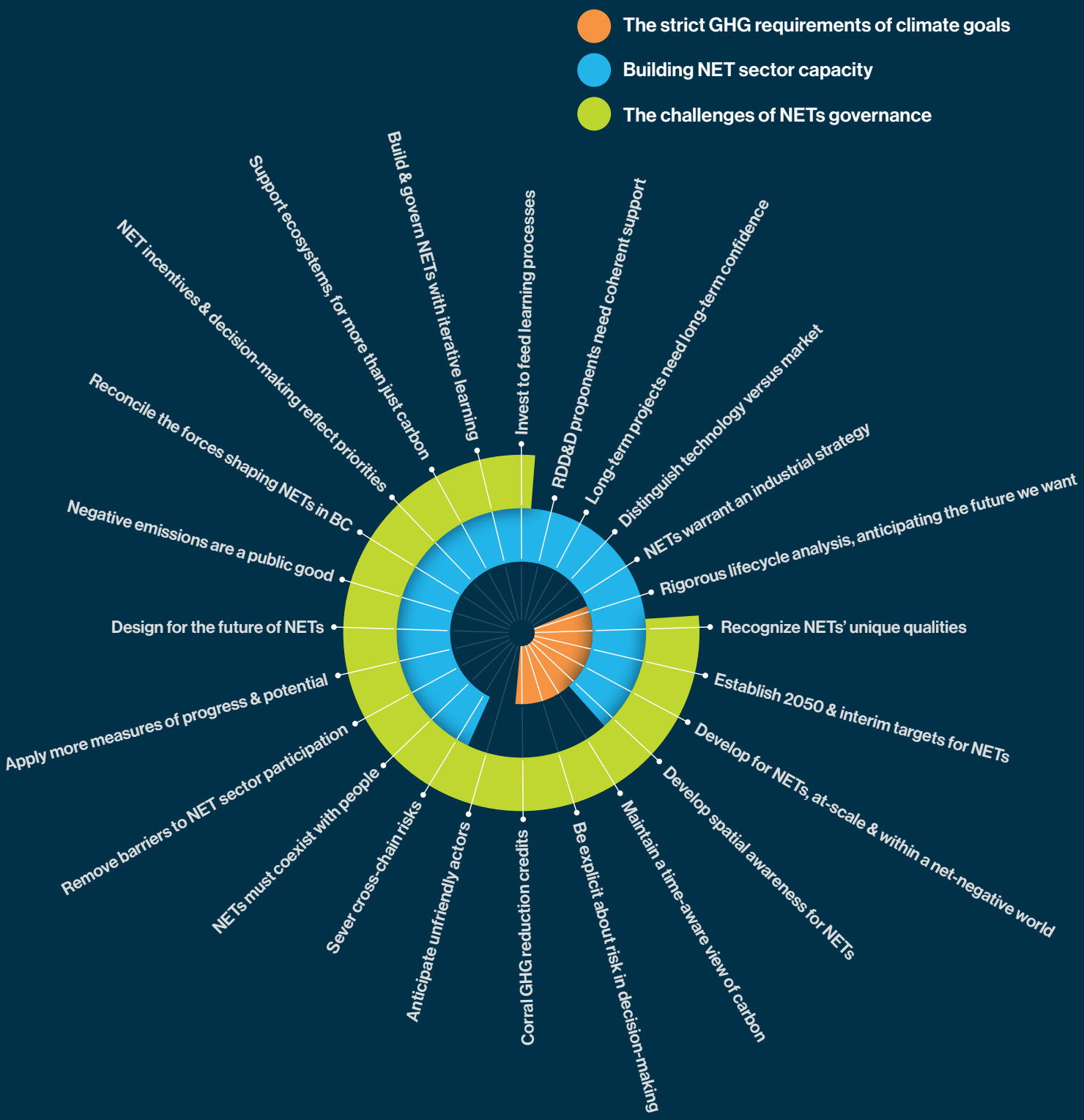
Element	Rationale	Examples
 **The global role of BC NETs**	BC could export negative emissions outcomes and/or NET expertise. Exporting outcomes from domestic projects implies developing a surplus of capacity, with all its concomitant implications, but it also reframes the distributions of benefits and burdens, and asks how export-destined projects and outcomes might be governed (e.g., will an unregulated shadow NET sector emerge?). Exporting expertise opens analogous questions within receiving jurisdictions. Power dynamics between actors within and across jurisdictions risk exploitative relationships negatively impacting BC and/or foreign recipient communities. Nevertheless, BC may have the biophysical capacity and motivation to diversify its economy towards a net-zero future.	> BC is a market leader for negative emission exports and is recognized for issuing quality credits against its diversified portfolio of NET projects. > BC is a destination for NET investment and export leader of expertise, whose leadership is augmented by strong ESG standards, improving both domestic and international outcomes.
 **NETs, lands and waters**	NETs and supporting systems will require space and resources. Depending on the NET and context, a project may disrupt or enrich local ecology, inclusive of the relationships with people. There are implications for the distribution of benefits and burdens, and for the processes by which projects are conceived, endorsed and undertaken. How are values and priorities reflected over extended time scales and geographies?	> Lands, waters and their residents are recognized as being more than NET machinery. There is consciousness to practise what works where it works, and to look beyond harm-avoidance and pursue strengthening. > Recognizing the need for social sustainability and the value of place-based knowledge, NET projects are coproduced and comanaged with communities. > NET design and siting do not steamroll local, vulnerable or politically marginalized communities; nor are they dominated by transactional relationships or private control of land.

Element	Rationale	Examples
 **NETs and forestry in BC**	Several NETs use forest ecosystems to capture and optionally sequester carbon, with different implications for how land may be converted and managed (e.g., afforestation, enhanced forest management, bio-energy/products and carbon capture). Meanwhile concern exists around climate change and management practice-enhanced disturbances (e.g., pests, wildfire, drought); the environmental and economic sustainability of current harvest practices; and the loss of old growth and other irreplaceable or sensitive habitats. Realizing credible forest-based NETs may demand a reckoning of the harvest sector and the broader relationships tied to forest ecosystems.	> Recognizing the human element within "natural" disturbances, BC adopts GHG targets inclusive of all land emissions and ensures the additionality of its forest-based NETs. > BC forestry has transitioned away from primary forest harvest, avoiding release of its carbon stocks and the NETs needed to negate any time-variable gap.
 **NETs and marine ecosystems in BC**	A subset of NETs situates in open and shoreline ocean ecosystems with different implications for how local ecology may be altered (e.g., nutrient fertilization, ocean alkalinity enhancement, algae cultivation and more). Some of these propose significant non-CO_2 material additions or removals to waters to alter the bulk chemistry or stimulate net primary production. Meanwhile, BC has vast shorelines, making ocean-based NETs an attractive opportunity. Here, NET priorities may intersect with those of restoration and protection, fisheries and mariculture, reducing ocean acidification, and others. However, BC also faces economically vulnerable coastal communities and profound concerns with its marine life populations. There is also a complex jurisdictional environment that could impair provincial guidance.	> Ocean-based NETs in BC are encouraged by a regulatory framework[8], coproduced by federal, provincial and local governments. > Ocean-based NETs enhance ecosystems and the livelihoods of coastal residents.

[8] Consider the precedent offered by the *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act*, and the *Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation (Nova Scotia) Act* (the Accord Acts).

Principles for NETs

Principles guide the development of policy actions working towards a vision. They provide the essential compass for navigating decision-making in an environment of uncertainty and of divergent priorities and values. BC could benefit from such guidance, but it needs to first articulate its principles for NETs. Synthesizing the ideas in this document, we suggest that a minimum set of principles should respond to:



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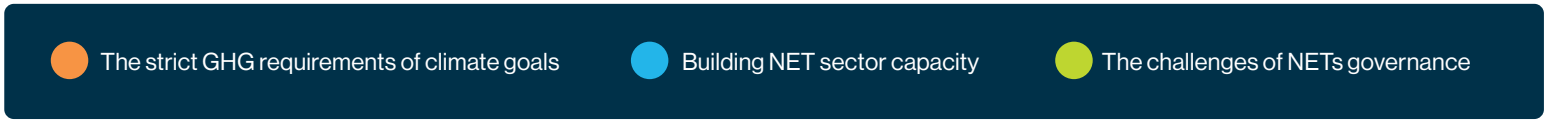
What follows is a sketch of possible principles of a NET strategy. It comes with the same caveats as our suggestions for a vision, adding that we cannot anticipate all the potential feedbacks to the increasingly action-oriented ideas. Within, some ideas may recur in different contexts or in more granular detail. Again, it is a resource alongside others (e.g., [32–34]) that may be drawn on within a broader public process.



Recognize NETs' unique qualities

Negative emissions are not interchangeable with emissions reductions, and neither are NETs interchangeable across different technologies or projects. Unfortunately, at present, it is common for the outcomes of removals versus reductions to be treated equivalently; over-reductive characterization of NETs themselves; and, perhaps, overconfidence in the ease with which NETs may be delivered. Negative emissions are a unique service. The many solutions constituting NETs should be addressed as a sector with coherent policy.

Establish 2050 and interim targets for NETs

Interim targets (e.g., 2030, 2040, 2050 and onwards) act on the urgency for building NET capacity. This NET trajectory should be set in the context of emissions trajectories for the rest of the economy, which makes explicit the intent of NETs prolonging — or not — practices near business as usual. Targets should be updated as activities unfold. Further technology-class targets might also be established. Overall, NET targets are a complement, not a replacement, to total GHG targets.

Develop for NETs, at-scale and within a net-negative world

NETs must grow with supporting infrastructure and coexist with other components of net-negative world. NETs cannibalizing decarbonization resources risks a no-win scenario where NETs cannot remedy intractable positive emissions. Conversely, NETs could work synergistically with other sectors. NET roadmapping may establish expectations for general types of NETs. Meanwhile, these should inform related sectors: forecasting of demand, capacity planning and system integration.

Develop spatial awareness for NETs

Developing spatial awareness works to bridge local, project-level insights to the strategic level. Siting of NETs and related systems may drive potential capacities and effectiveness, and shape how NETs are received within existing industries and communities. Development could emerge project-by-project or be master-planned, and could be undertaken by centralized or polycentric bodies. Who is empowered in estimating, planning and deployment decision-making will need to be established. Clear guidance may reduce uncertainty for frontline communities and NET proponents, and inform policymakers' convergence towards NET targets.

Corral GHG reduction credits

Or even retire the concept. Credits derived from initiatives which merely reduce or avoid GHG emissions should not unfairly compete with GHG removals (NETs) within the same markets or regulatory compliance schemes. Meanwhile, the idea of reductions will grow meaningless as we decarbonize and baselines of additionality evolve.

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Be explicit about risk in decision-making

Strategy development and public participation should promote more public discussion about the confidence with which GHG and NET targets may realize climate outcomes, and the challenges of meeting and the anticipated robustness of NET portfolios. This may build credibility for a proactive policymaker role in NETs, and for contemplating more types of value within portfolio development.

Maintain a time-aware view of carbon

In particular on the security of long-term sequestration, and on the timeliness of agriculture, forestry and other land use (AFOLU) biogenic carbon releases and drawdown. AFOLU practices may create unfavourable transient increases in atmospheric GHGs, even if reversed over the long-term (e.g., primary forest harvesting or conversion of productive grasslands). Meanwhile, NETs are only effective with essentially indefinite storage. Changing climate, policies, negligence, abandonment and more could contribute to carbon return to the atmosphere. Consequently, solutions managing labile storage over limited terms (e.g. 100 years) have limited utility.

Negative emissions are a public good

Everyone benefits from addressing climate change, and the benefits of GHG removals are universally shared. Policymakers have key responsibility over the near- and long-terms. Over the near-term we must catalyze the development of a NET sector, while over the long term we must ensure the sectors' effectiveness and sustainability. Economic sustainability in particular may demand plans for evolving the distribution of responsibility across polluters and public financing.

Reconcile the forces shaping NETs in BC

At present, plans for NETs within BC may be influenced by incoherent forces originating from regulatory and voluntary GHG systems in BC, Canada and foreign jurisdictions. However, the priorities and quality of programs may vary, accountability is fragmented and issues of double-counting may arise. Public sentiment may suffer if export-destined projects are not aligned with expectations or are high grading local NET capacity. If a fit-for-BC NET portfolio is desired, local policymakers might assert regulatory oversight over the production, consumption and export of negative emissions outcomes.

NET incentives and decision-making reflect priorities

NETs technologies and projects are heterogeneous. Our current paradigm driven by fungible credits priced per tonne of CO_2 may be convenient but alone risks being too blunt to incentivize a desired NET portfolio or to make considered R&D and commercial decisions. Instead, evaluations should consider a richer set of merits including: contribution to capacity; growth potential; robustness; co-benefits/harms; knowledge production; and more.

Support ecosystems, for more than just carbon

These are NETs based on the conversion, restoration or management of ecosystems with carbon sequestration within soils and plant biomass (i.e., not cropped). Swift action is motivated by launching early the slow processes of carbon accumulation. Still, outcomes may be hard to predict; the carbon is labile; and non-NET priorities might be stronger determinants of intervention (e.g., avoided degradation, ecosystem services, conservation, cultural values, etc.). Where possible, create targeted incentives that

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avoid competition with other NETs, and promote ecosystem strengthening, where negative emissions may simply be a co-benefit (i.e., no regrets).

NETs warrant an industrial strategy

The urgency and importance of securing sufficient NETs warrants a whole-sector industrial strategy. They must be pulled out from current sectoral silos. The absence of an established sector and the complexity of NETs further supports a proactive role from policymakers. A strategy should seek to combine the agility and ingenuity of the private sector with the long-term risk capacity of the public sector. It should also develop public analytical capacity to support defensible decision-making and democratized knowledge.

Build and govern NETs with iterative learning

Learning processes can adapt to uncertainty in NETs' technical outcomes; fit with existing systems; and fit within a net-zero transition. The circumstances facing NETs will change as we address climate change. Among other elements, a process should seek to institutionalize knowledge publicly; be proactive in responding to issues of justice and equity; and draw on diverse forms of and place-based knowledge. Learning must be accompanied by a commitment to adapt strategy and policy actions.

Invest to feed learning processes

We want a NET portfolio aligned with our vision but the challenge is not knowing precisely what that composition looks like in advance. A strategy should promote building both NET capacity and knowledge. Learning-by-doing implies making investments towards testing ideas. This is applicable to all stages of development and may be particularity impactful when financing pilot and larger-scale initiatives that might otherwise be bottlenecked by scaling uncertainties. Here, policymakers might commit to building a portfolio of first-of-a-kind projects, designed and managed to generalize the most learning outcomes.

Rigorous lifecycle analysis (LCA), anticipating the future we want

LCA quantifies NETs' overall GHG outcomes inclusive of operational and embodied contributions. Analyses should be timely and have rigour matched to the magnitude of a project or investment. These should also respect additionality and assume a net-zero future baseline. There is a role for policymakers to define what a net-zero future entails and potentially to support proponent analysis capacity. As NETs scale-up, they may increasingly shape the systems outside of the analysis boundaries and alter the accounting of land-use change; energy; consumables (especially stoichiometric quantities); market uptake (and limits thereon) of by-products/wastes; and more.

Design for the future of NETs

NETs are a certainty for any 1.5°C future. To the extent that we define a vision of the technologies and participants, we might identify actions to support development spanning emergence, diffusion and reconfiguration. This contrasts serial action on a per-technology or per-project basis. Concurrent actions may comprise technology R&D and scaling; developing scaling capacity (e.g., supply chains and manufacturing); and developing and debottlenecking governance.

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RDD&D proponents need coherent support

Developing NETs also means developing the actors pursuing the effort. At present, innovators can be left stranded by a fragmented and generic ecosystem of incentives across the different stages of technology development. A strategy should replace this with a continuity and critical-mass of programs targeting NETs. These should situate within an overarching institution that is equipped to manage NETs' unique risks and opportunities, and that is charged with advancing a portfolio aligned with the long-term NET vision.

Long-term projects need long-term confidence

Large-scale NET projects must run over decades to perpetuity, and may have sustained operational and/or large upfront costs. Financing requires confidence in the long-term cashflows and the regulatory environment. Spot markets for credits do not offer confidence, whereas voluntary futures may be insufficient and/or unmatched to jurisdictional portfolio goals. If private capital participation is sought, a strategy should provide compatible tools and environment.

Distinguish technology versus market

The currently immature NET market may be overly-reflective of business acumen versus solutions' technical merits, and risks misplaced effort into suboptimal solutions or even charlatans. Instead, funding and similar decision-making should distinguish candidates' technical and market readiness and potential, and further disentangle candidates' technical composition. The goal is to encourage targeted support geared to candidates' strategic advantage, bottlenecks and drivers of success.

Apply more measures of progress and potential

Alternative measures (versus the typical unit of tonnes CO_2) can serve as indicators for progress and as basis for distributing incentives. Tailored to different NET classes, readily measured proxies can close the policy loop faster. This may be particularly useful for overcoming bottlenecks due to uncertainty and for gauging latent potential of second- or later-generation refits. This challenges our current paradigm of fungible credits, yet can work together with other principles seeking recognition of co-benefits, co-harms, innovation learning, etc.

Remove barriers to NET sector participation

Who is able to participate in NETs prompts thought on justice and equity, and the meaning of a just transition. Existing, often emissions-intensive, industry may be advantageously positioned to play a key role in NETs. Policymakers should avoid private capture of NETs by incumbents, and should encourage participation from smaller, newer entrants. Opportunities may exist in democratizing access to institutionalized knowledge and infrastructure; managing regulatory overhead; pooling technology and market risks; and more.

NETs must coexist with people

NETs require social sustainability at large and at project-level scales. Failure risks obstruction or abandonment. Coproduction offers an alternative to the status quo of adversarial consultation. Here, local, right-scaled, and representative community bodies collaborate on project development and management. This ideally encompasses operational and business dimensions, allowing reflection

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of participants' priorities and values. Thus, projects can build shared interest in success while benefiting from local expertise. They further become potential pathways to address inequities and vulnerabilities.

Sever cross-chain risks

At present, there is a lack of robust supply or markets for constituent elements of NET value chains, including the downstream market of credits; supplies of equipment and feedstocks; and access to logistics, sequestration and other infrastructure. This creates undue cross-chain risk and encourages everything-or-nothing business models (e.g., vertical integration) which can be difficult for new and would-be participants to assemble. Severing cross-chain risks seeks to remove, reduce and distribute risks amongst value chain participants. This can remove barriers to participation from smaller, specialist organizations. It can also create more entry points for new innovations to plug into, or reconfigure new value chains.

Anticipate unfriendly actors

NETs are potentially disruptive. It should not be assumed that parties will work toward compatible visions or policies. They may seek to stonewall NETs entirely; co-opt NETs toward special interests; game policies; or seek monopoly over key NET building-blocks. Private capture of solutions may be particularly concerning if policymakers are providing the enabling investments. We should anticipate how NETs might be subverted from the outset and work accordingly.

Exploring (a few) solutions

This section imagines solutions which might support the growth and longer-term sustainability of NETs within BC. It responds to preceding sections' suggested vision and principles, although full agreement is not necessarily required to draw inspiration from the ideas. The more essential assumptions are:

> We urgently need to develop NETs at scale.

> We need a portfolio of solutions comprising multiple types of NETs.

> Public institutions have a crucial role to play in mobilizing public and private resources.

How to create a reliable demand-side for negative emissions is an open question, which we recognize as a bigger debate about GHG and climate accountability, as much as it is about efficient policy. At present, the space of NET-centric policy incentives is thin.

Within Canada, there is the Canadian Greenhouse Gas Offset Credit System [35]. However, it equates emissions reductions and removals, and while it certifies credits for the program, it does not provide a platform for exchange. In the US, there is the 45Q carbon capture tax credit, which makes DAC-based systems eligible at smaller scales versus point source CCS projects and, with the recent Inflation Reduction Act (IRA) update, provides a premium for DAC-based systems. Also within the US is the California LCFS CCS Protocol, which allows DAC-based NETs located anywhere in the world to qualify, and which may be stacked with 45Q credits. The Global CCS Institute has published a summary of these US programs pre-IRA [36]. Such pollution pricing may continue to escalate, but we may need further targeted NET policy if we are to achieve necessary scales.

An example of international cooperation is the recently launched (November 2021) Mission Innovation's Carbon Dioxide Removal Mission [37], which aims to grow a global

Federal Minister of Environment and Climate Change Steven Guilbault announces Canadian Greenhouse Gas Offset Credit in March 2022. (Flickr: PMTrudeau)

NET industry to at least 100 $MtCO_2$/yr by 2030 through R&D, harmonized analyses and facilitating early deployments. This initiative is co-led by Canada, the United States and Saudi Arabia. In the United Kingdom, there is presently a £100-million (C$154.6-million) Direct Air Capture and other Greenhouse Gas Removal technologies competition [38], which is on its second phase of supporting the piloting of key components and furthering solution designs. In the US, the Department of Energy's (DOE) *Energy Earthshots Initiative* features a *Carbon Negative Shot* [39], which aims to drive innovation across an array of NETs to achieve gigatonne-scale removals by 2050 at less than US$100 per tonne CO_2. And in May 2022, the US DOE released a notice of intent to fund the Bipartisan Infrastructure Law's USD$3.5-billion program toward developing four large-scale regional direct air capture hubs [40].

General recommendations for further policy are offered by Friedmann et al. [41] for point source CCS and "engineered" NETs (e.g., DAC, BECCS and enhanced mineralization) comprising: infrastructure investments, strategies for valorizing CO_2 and debottlenecking regulation. Recommendations tailored to the United States are offered by Carbon180's Zero, Then Negative: The Congressional

Growing the NET sector requires the development of technology and material supply chains, such as the Forest Carbon Initiative and BC Timber Sales' Seedling Services.

Blueprint for Scaling Carbon Removal[42], comprising specific actions for federal bodies in support of R&D and deployment of both "land-based" and "tech-based" NETs. Finally, a model of specific NET legislation is OpenAir Collective's Carbon Dioxide Removal Leadership Act *(CDRLA)*[43], a public procurement model. A version of the CDRLA is being deliberated in New York State, and the OpenAir community is looking to expand the model in the US and internationally.

> *At present, the space of NET-centric policy incentives is thin.*

Building on these solutions, our overarching recommendation is to: envision how NETs will work in the future; convene key participants; and, through a roadmapping process, identify the best steps to grow the sector. Keeping the whole-sector context in mind, this should engage the granular detail within classes of NETs and NET building blocks. A key consideration is scaling supporting systems to accommodate the necessary growth in NETs; for example:

- Building electrical and/or thermal energy capacity considering DAC and BECCS. In British Columbia, BC Hydro is centrally positioned and could be empowered to plan and invest over long horizons. Its mandate is already being evolved to support *CleanBC* electrification plans[19] and could expand to anticipate NETs.
- Developing technology and material supply chains, which applies to both abiotic and biogenic solutions, and is amplified for those NETs with stoichiometric volumes of consumables or products. In BC, the Forest Carbon Initiative and BC Timber Sales' Seedling Services already run initiatives (e.g., on seedlings, fertilizer, biomass utilization and logistics). Also in BC, Carbon Engineering is a leading DAC technology company and recent federal investment into Svante's manufacturing capacity[44] indirectly contributes to DAC-relevant solid sorbent capacity. These initiatives could be expanded and refocused upon carbon removals.
- Developing governance, which includes crafting or revising the laws and regulations to enable the various practices constituting NETs. This also includes establishing processes for integrating public communities within NET development — and perhaps improving on current models, as recent flashpoints around fossil and even green infrastructure suggest the status quo risks project obstruction, and potentially poisoning the well of public acceptability.

We also suggest reconsidering how NETs and supporting systems are configured, as scale has limited use if it is not accessible. This is illustrated by a few short sketches imagining the needs and solutions of a future NET sector. The solutions are adapted from analogous problems with Canadian policy precedents, conferring, it is hoped, a sense of feasibility.

CO_2 transportation and geosequestration infrastructure

Transportation and sequestration are required for future CO_2 point sources which may derive from hard-to-abate sectors alongside DAC and BECCS NETs. We envision a provincial public utility whose scale and public backing could:

- integrate NETs into planning;
- guarantee access to participating capture and sequestration projects;
- achieve wider, equitable, geographic connectivity;
- reduce risks for participants and the utility through reliable toll rates and by pooling cross-chain risks;
- streamline permitting and establishing rights-of-way; and
- invest in larger capacities compatible with long-term needs.

CO_2 transportation and sequestration are technically well understood and have been applied in many cases around the world. This leaves non-technical risk as perhaps the bigger bottleneck. Precedents suggest the capacity for public investment and regulation of essential infrastructure, including:

- Quest CCS project, which includes pipeline transportation and a sequestration facility, developed by Shell and primarily financed by the Alberta and federal governments;
- Alberta Carbon Trunk Line (ACTL), a privately owned, open-access pipeline financed by the Alberta and federal governments, and whose owner/operator (Wolf Midstream) has the Canada Pension Plan Investment Board as an investor; and
- British Columbia Utilities Commission (BCUC), the provincial regulator for common-carrier pipelines responsible for service, toll rates and fairness. Meanwhile, the BC Oil and Gas Commission regulates provincial oil and gas pipeline from safety, environment and public perspectives.

Incorporating CO_2 transportation within BCUC's mandate might address toll rates and access but is alone unlikely to stimulate adequate sequestration or infrastructure creation. Meanwhile, merely expanding project-by-project public investments locks in narrowly conceived private developments (witness hydrocarbon-centric development in Alberta) and risks opaque public ROI and accountability. Instead, shifting to a utility mindset might confer tighter integration of public-investment capacity and policymaker ambitions for carbon management. This could carry a mandate to support growth-oriented infrastructure, including serving the scale-up of NETs.

The Alberta Carbon Trunk Line will gather CO_2 from industrial emitters in Western Canada and convey it to reservoirs across Central and Southern Alberta. CO_2 will initially be captured from the Sturgeon refinery complex shown above.

A biomass exchange for NETs

NETs relying on cropped biomass require reliable sources with certainty regarding their GHG intensity (e.g., BECCS, biochar and other recalcitrant biocarbon products); this applies to both purpose crops and residues. They also need guardrails to protect against deleterious land-use change or competition with food production. GHG outcomes may be risked at any stage of sourcing, logistics and processing. We envision a public monopoly on buying and marketing for biomass destined for NETs could:

- reduce barriers to participation from small-scale participants;
- track and guarantee negative emission outcomes;
- carry LCA overhead on behalf of arbitrary combinations of producers, processors and logistics providers;
- match biomass sources and sinks for optimum GHG outcomes, and equitably distribute compensation;
- pool uncertainty on production (including AFOLU) and transportation;
- provide mechanisms for near- and long-term price certainty; and
- provide a layer of privacy for sensitive commercial data that might otherwise be exposed in an open market.

Precedents suggest the capacity for a public role in managing the regulation and data pertinent to GHGs and biomass, and for controlling trade.

For example:

- The BC Carbon Registry, which manages credits for BC's regulatory GHG programs and is open to voluntary purchasers, includes projects integrating biomass use, and requires proponents seek independent validation and verification of plans and outcomes.
- Stumpage fees are collected on timber harvested from public land in BC, which is based on data tracking timber volumes, species and grades.
- Co-operative wheat pools and the federal Canadian Wheat Board, which were central buyers and marketers of grain operating on behalf of producers, and featuring payment structures to manage risk.

The absence of centralized biomass exchange is unlikely to halt associated NETs. However, self-organization burdens participants with qualifying every supply chain configuration; and may leave unrealized negative emissions within how the network of elements is connected because some entities will be unable to bear the overhead. A first step of public exchange with integrated LCA expertise and data collection, may provide participants both flexibility and streamlined, regulatory-compliant GHG accounting. A further step toward a single desk may confer additional capacity for optimizing biomass flows, and for managing GHG and price/supply uncertainties.

Flavelle Sawmill in Port Moody, BC.

A carbon public utility

Policymakers require oversight of the quantities and qualities of negative emissions generated within the province. NETs themselves require institutions for sustainable financing through a net-zero transition and beyond. We envision a public utility facilitating NETs project development and the exchange of negative emissions outcomes could:

- track progress towards a NET vision;
- introduce public accountability into a patchwork of regulated and unregulated operations;
- provide a vehicle for strategic public investments (e.g., in first-of-kind projects), and for future funding as a public good;
- create a forum for low-barrier private producer and consumer participation, and for project-enabling financing; and
- manage risk arising from NET technical outcomes and counterparties.

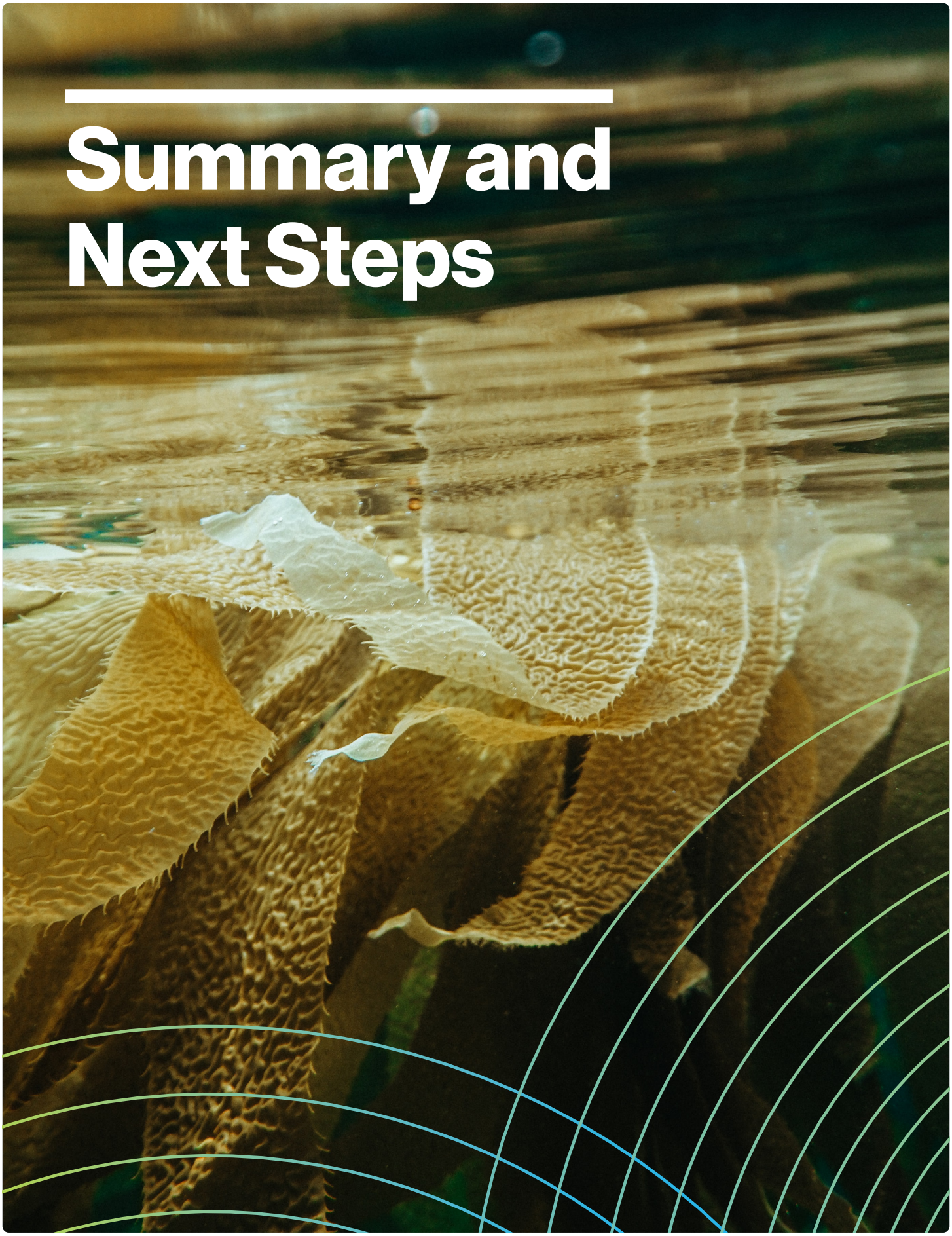
Precedents suggest the capacity for a public institution to operate an exchange, procure and market credits, and develop large capital projects, potentially with private participation. For example:

- The BC Carbon Registry manages the issuing, transfer and retirement of credits destined for compliance with BC's regulatory GHG programs and for voluntary purchasers.
- The government-run British Columbia carbon offset portfolio procures offsets on behalf of the public sector to meet carbon-neutral government commitments. It assumed the role from the ill-fated Pacific Carbon Trust, which faced issues of opacity and dubious credit quality[45].
- Regulated electricity markets and utilities are models for delivering service; building long-term capacity (e.g., via capacity auctions, and private and public power purchase agreements); and running additional programs for reliability. BC Hydro is an example public electrical utility and is also an international product exporter via its subsidiary Powerex Corp.

As is, the current patchwork of NET participants is unlikely to realize any vision for the sector. Incremental regulation might shift public program focus from GHG reductions to removals, and harmonize activities within a central public registry. Targeted public procurement might also influence the sector's growth. However, these actions may leave the private market to mostly organize itself, and leave no entity minding the integrity of the provincial NET portfolio. In contrast, a public carbon utility that procures and markets negative emissions on behalf of all may ensure accountability for individual projects and the portfolio; growth with levers for NET quantity, capacity and composition; and reliable negative emission outcomes at stable prices.

A city waste management vehicle in Victoria, BC.

Summary and Next Steps



Where do we go from here?

NETs are practices that remove GHGs from the atmosphere to address climate change. If we are to stabilize climate change and meet our 1.5°C Paris goals, significant scales of NETs together with drastic reductions in positive emissions are required. BC shares in this global responsibility but also has the potential to make an outsized contribution and generate economic benefit.

We know what general options are available for NETs but an organized sector does not exist yet. Nevertheless, NET proponents, including developers, financiers and marketers, are emerging based on demand from the few organizations pursuing voluntary GHG removal goals, and based on speculation about what policy may arise. Within this opaque and unregulated space, there may be doubt in the credibility of additionality and net permanent removals, the scalability of solutions and whether the jurisdiction-wide portfolio is sustainable in the long term. The effect is that no one is at the helm directing us towards sufficient quantities of NETs, with the right qualities, for the right reasons.

> *We need to strategize more effectively and to set richer objectives than mere quantities of negative emissions.*

We also know that within BC and Canada, we have consistently failed to achieve GHG emissions-reduction targets. Further, we tend to do poorly in translating innovation investments into productivity. A likely continuation of this pattern would see us eventually being inspired to make NETs a priority, making a naïve application of our standard strategic practices and reacting with surprise at our subsequent failure. Added complexity arises from NET development being interconnected with the resources and infrastructure required by the rest of a net-zero transformation, and from unchecked NET development risking prolonged net-zero incompatible practices. Meanwhile, simplifying matters is certainty in the long-term domestic need and, likely, export

A demonstrator at the 2021 United Nations Climate Change Conference in Glasgow (COP26).

opportunity. The upshot is that we need to strategize more effectively and to set richer objectives than mere quantities of negative emissions.

It is under these circumstances and an urgency to act in face of serious climate change consequences that we recommend the development of a provincial strategy for NETs. We further recommend that this strategy adopt an approach that integrates the key participants on whom NET rely — a co-production approach — and that incorporates a visioning process making explicit the principles by which NET should be developed and fit within a net-negative future. A made-in-BC strategy can mobilize people and resources towards a shared goal, and position the province for global leadership in an emerging essential sector.

This report supports a response to these recommendations by outlining a framing of the NET challenge; essential functions within a co-production model; components of a strategy's vision and principles; and examples of policy actions adopting the former. In doing so, we were guided by:

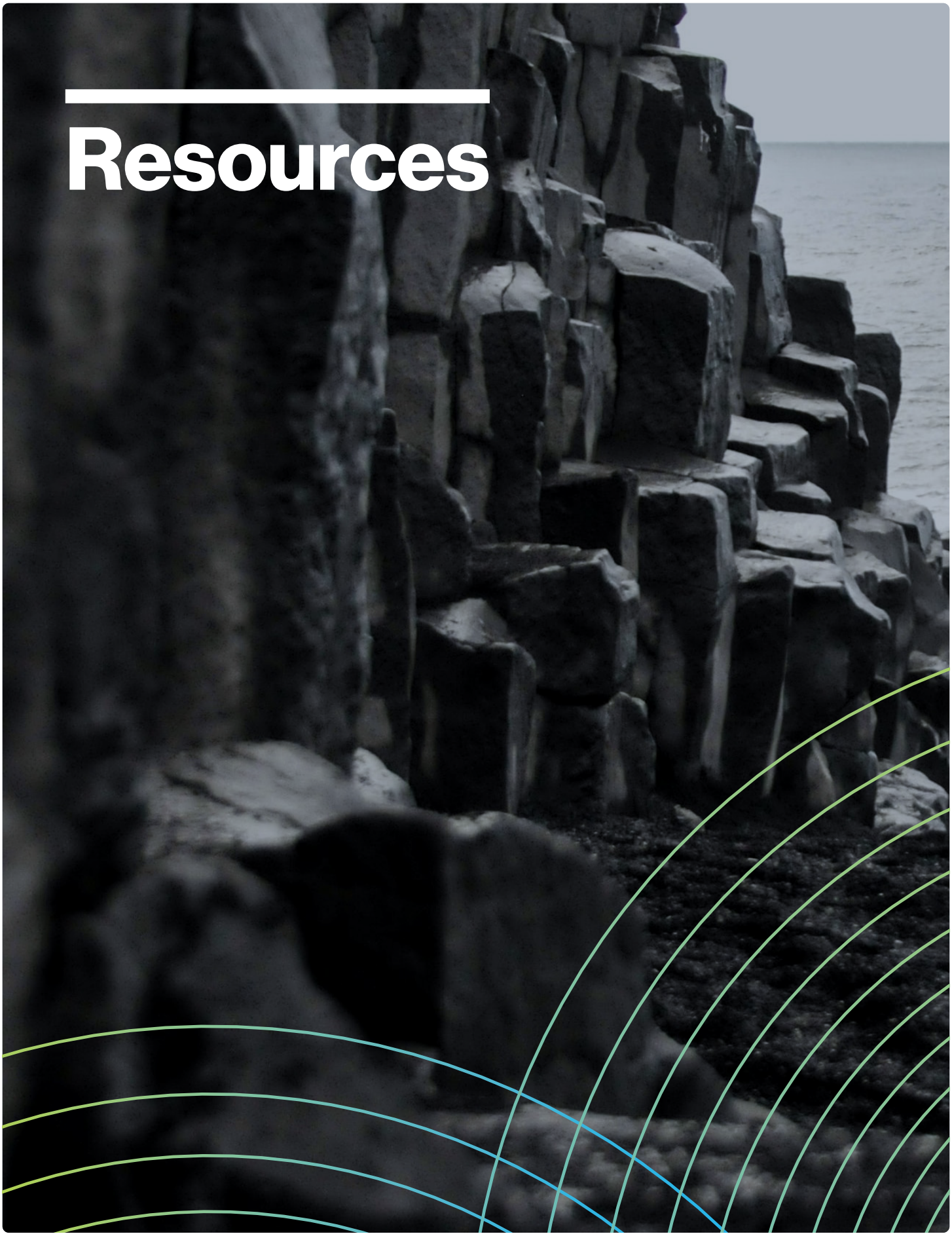
- recognizing NETs' unique role within climate action, and the technology- and project-specific attributes of different NETs;

- pursuing an adaptive NET portfolio, and how this means working through uncertainty with commitments to learning and to hedging across a plurality of solutions; and
- translating confidence in the long-term need for NETs into actions and institutions that can accelerate RDD&D and support the people behind it.

This report also serves as a primer for participants in what we propose as the next step in developing a provincial NET strategy: convening leaders within policymaking, industry and more who would be charged with developing a first iteration of a NETs vision and principles. This catalytic community is retained through our proposed subsequent steps of developing roadmaps specific to each NET subclass and synthesis to identify priority actions for the sector. We expect a collaborative effort demanding broad participation from across the province, including the public, and the Pacific Institute for Climate Solutions is here to help facilitate it.

Looking beyond, NETs will be just part of the profound transformations working towards stabilizing climate change, adapting to its consequences and maintaining a liveable society. We can strive to minimize the NET effort but we would be foolish to neglect it.

Resources



Where to learn more

We invite readers to further explore NETs and the context in which they fit. We offer the following list of resources as a starting point.

Learn more about NETs

J Wilcox, B Kolosz, and J Freeman (eds.)
CDR Primer (2021)
https://cdrprimer.org/

The National Academies of Sciences, Engineering, and Medicine
Negative emissions rechnologies and reliable sequestration: A research agenda (2019)
https://www.nap.edu/catalog/25259/negative-emissions-technologies-and-reliable-sequestration-a-research-agenda

A research strategy for ocean carbon dioxide removal and sequestration (2021)
https://www.nap.edu/catalog/26278/a-research-strategy-for-ocean-based-carbon-dioxide-removal-and-sequestration

The Royal Society and the Royal Academy of Engineering
Greenhouse gas removal (2018)
https://royalsociety.org/topics-policy/projects/greenhouse-gas-removal/

Current GHG emissions and the big picture

IPCC
Sixth assessment report (AR6)
https://www.ipcc.ch/assessment-report/ar6/

Province of British Columbia
Greenhouse gas emissions data and inventories
https://www2.gov.bc.ca/gov/content/environment/climate-change/data

How NETs may fit within society

David R. Morrow et al.
Principles for thinking about carbon dioxide removal in just climate policy (2020)
https://www.cell.com/one-earth/pdf/S2590-3322(20)30359-6.pdf

Holly Jean Buck
After geoengineering: Climate tragedy, repair, and restoration (2019)
https://www.versobooks.com/books/3091-after-geoengineering

Myles Allen et al.
The Oxford principles for net zero aligned carbon offsetting (2020)
https://www.smithschool.ox.ac.uk/publications/reports/Oxford-Offsetting-Principles-2020.pdf

Wim Carton et al.
Undoing equivalence: rethinking carbon accounting for just carbon removal (2021)
https://www.frontiersin.org/articles/10.3389/fclim.2021.664130/full

Wim Carton
F*ixing climate change by mortgaging the future (2019)*
https://onlinelibrary.wiley.com/doi/full/10.1111/anti.12532

On transition to a net-zero world

Bentley Allan et al.
Canada's future in a net-zero world: Securing Canada's place in the global green economy (2022).
https://institute.smartprosperity.ca/publications/CanadasFuture

James Meadowcroft and contributors
Pathways to net zero: A decision support tool (2021)
https://transitionaccelerator.ca/pathwaystonetzeroreport/

D.G. Victor, F.W. Geels, and S. Sharpe
Accelerating the low carbon transition: The case for stronger, more targeted and coordinated international action (2019)
https://www.brookings.edu/wp-content/uploads/2019/12/Coordinatedactionreport.pdf

NET leadership in the corporate sector

Selected for their open-access insights into evaluation criteria and projects.

Microsoft's carbon removal program
https://www.microsoft.com/en-us/corporate-responsibility/sustainability/carbon-removal-program

Shopify's sustainability fund
https://www.shopify.ca/climate/sustainability-fund

Stripe climate
https://stripe.com/en-ca/climate

NGOs, networks, and academic institutions

Several run informative events, and maintain their own lists of learning resources.

AirMiners
https://airminers.org/home

Carbon180
https://carbon180.org/

CarbonPlan
https://carbonplan.org/

CDR Law
https://cdrlaw.org/

ClimateWorks Foundation's CDR Program
https://www.climateworks.org/programs/carbon-dioxide-removal/

Institute for Carbon Removal Law & Policy
https://www.american.edu/sis/centers/carbon-removal/

The OpenAir Collective
https://openaircollective.cc/

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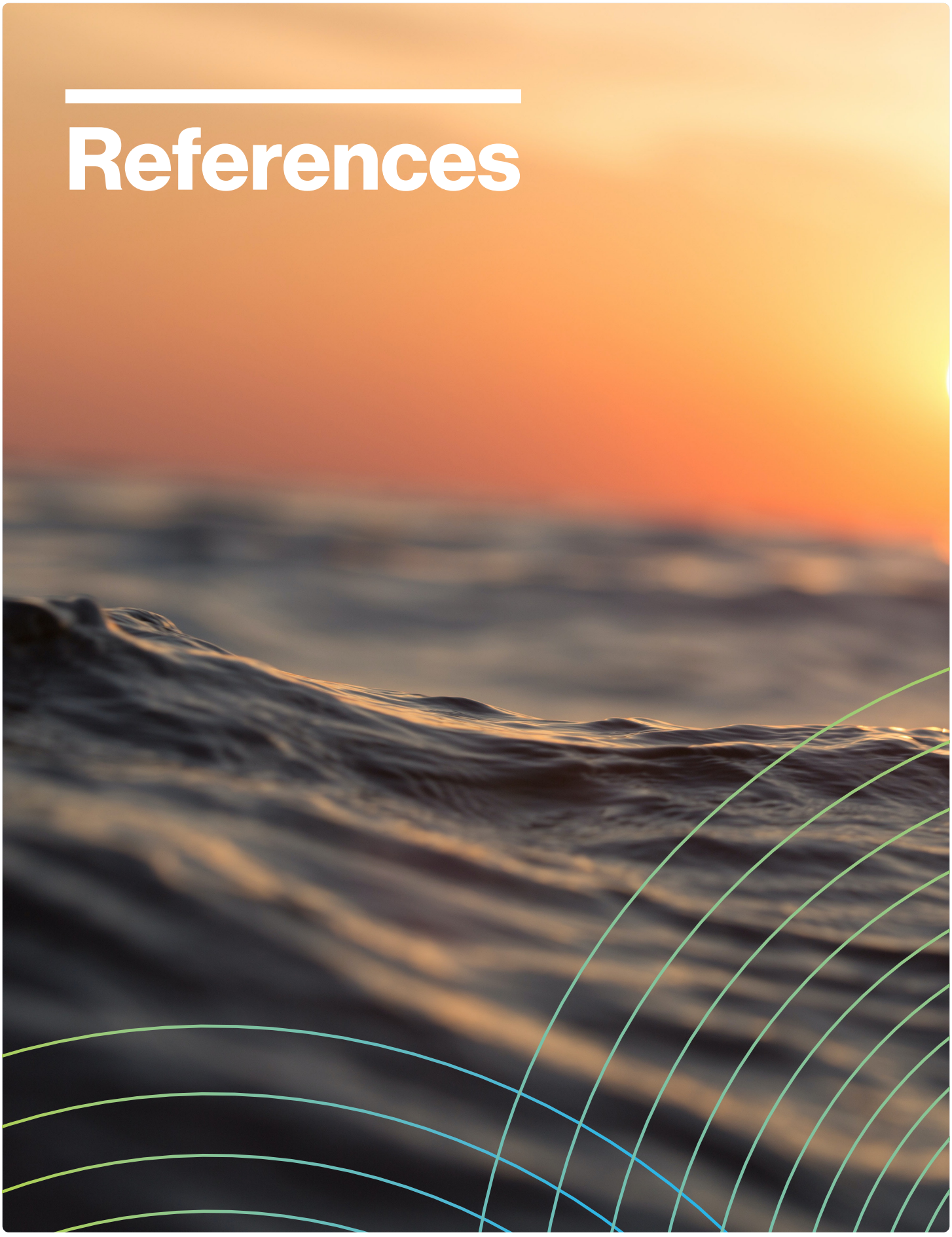

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