



Center for Sustainable Economy



An Analysis of Carbon Market Opportunities for Adventure Scientists

Memorandum 1: Carbon Market Overview

By

John Talberth, Ph.D.
Senior Economist
Center for Sustainable Economy
1322 Washington Street Box 705
Port Townsend, WA 98368
(360) 344-2080
www.sustainable-economy.org

July 2023

I: Overview

As nations, business leaders and individuals increase their level of ambition to combat climate change the role of carbon markets has drastically expanded. Carbon markets provide a mechanism for entities whose operations generate greenhouse gas (GHG) pollution and face high costs of reducing that pollution to purchase carbon credits generated by emissions reduction or prevention activities of other entities with lower costs to achieve their mandatory or voluntary emissions reduction goals. Carbon credits represent the basic unit of trade and are expressed in metric tons carbon dioxide equivalent (tCO₂-e) avoided or removed from the atmosphere.

These credits take the form of unused allowances for GHG pollution allocated or auctioned through mandatory emissions trading schemes (ETSs) or carbon offsets developed and registered by corporate, non-profit, or in cases government entities. This series of memoranda will focus on the latter – carbon offset credits – and identify opportunities for Adventure Scientists to participate in this growing market by training and deploying citizen scientists to collect field data essential for high quality carbon credit commodities. Carbon credits range from credits based on little more than paper promises to those monitored and verified on-the-ground through measurement. The four memoranda will focus on Adventure Scientists’ opportunities for providing services in support of high-quality credits that rely on robust field data and will include:

1. A basic overview of compliance, voluntary, and quasi-public carbon markets that create the basis for supply, demand, and trade of carbon credits. This will include a focus on credits generated by the UN’s Reducing Emissions from Deforestation and Forest Degradation ‘plus’ program (REDD+) since it is the largest source of higher quality credits from natural solutions.
2. An analysis of where field data is used in the generation and verification of carbon credits.
3. Results of interviews with key market participants to gauge their level of interest in using the services of Adventure Scientists.
4. Presentation of three or more business options for Adventure Scientists.

II: Carbon market configurations

There are three basic configurations of carbon markets that have created the impetus for the supply, purchase and trade of carbon credits: compliance offset credit markets, voluntary offset credit markets, and quasi-public offset credit markets supported by public investments.

Compliance offset credit markets

Under this configuration, governments establish clear quantities and timelines for reduction of GHG pollution from regulated entities and allow for the banking and trade of emissions reduction credits from entities that surpass their compliance obligations. These emissions trading schemes (ETSs) also allow regulated entities to use credits purchased from carbon offset projects to meet a small portion of their emissions reduction obligations each year. Protocols and standards related to the supply, purchase, and trade of these credits is a matter of public policy

The World Bank issues periodic updates on the status of these compliance (ETS) markets. Figure 1 depicts the current (2023) geographic extent of ETS as well as carbon tax schemes across the world.² There are 72 individual programs. Areas shaded in purple or blue are places where ETS and carbon tax programs have been implemented or are scheduled. Not all these programs are ones that generate offset credits. Figure 2 is a map of areas where offset crediting mechanisms are being implemented (dark green) or are under development. “Implemented” crediting mechanisms have the required framework (e.g., legislative mandate) as well as the supporting procedures, emission reduction protocols and registry systems in place to allow for crediting to take place.

Legend:

- ETS and Carbon Tax Implemented or Scheduled
- ETS Implemented or Scheduled for Implementation
- Carbon Tax Implemented or Scheduled for Implementation
- ETS or Carbon Tax Under Consideration

Regions and Countries:

- North America:** Washington, Oregon, California, New York, Massachusetts, Pennsylvania, New Jersey, North Carolina, Mexico, Durango, Zacatecas, Jalisco, State of Mexico, Colombia, Brazil, Uruguay, Chile, Argentina, South Africa, Botswana, Senegal, Côte d'Ivoire, Gabon, Nigeria, Israel, Morocco, Iceland, Georgia, Kazakhstan, Turkey, Pakistan, China, Japan, Republic of Korea, Tokyo, Sakhalin, Lithuania, Latvia, Estonia, Czech Republic, Finland, Sweden, Norway, Denmark, Germany, Netherlands (Kingdom of the), Belgium, UK, Ireland, Luxembourg, Liechtenstein, France, Catalonia, Portugal, Spain, Italy, Switzerland, Austria, Slovenia, Hungary, Bosnia & Herzegovina, Albania, Montenegro, Greece, North Macedonia, Bulgaria, Serbia, Croatia, Romania, Moldova, Ukraine.
- Europe:** Norway, Denmark, Germany, Netherlands (Kingdom of the), Belgium, UK, Ireland, Luxembourg, Liechtenstein, France, Catalonia, Portugal, Spain, Italy, Switzerland, Austria, Slovenia, Hungary, Bosnia & Herzegovina, Albania, Montenegro, Greece, North Macedonia, Bulgaria, Serbia, Croatia, Romania, Moldova, Ukraine.
- Asia:** Japan, Republic of Korea, Tokyo, Sakhalin, Lithuania, Latvia, Estonia, Czech Republic, Finland, Sweden, Norway, Denmark, Germany, Netherlands (Kingdom of the), Belgium, UK, Ireland, Luxembourg, Liechtenstein, France, Catalonia, Portugal, Spain, Italy, Switzerland, Austria, Slovenia, Hungary, Bosnia & Herzegovina, Albania, Montenegro, Greece, North Macedonia, Bulgaria, Serbia, Croatia, Romania, Moldova, Ukraine.
- Oceania:** Australia, New Zealand.
- Other:** Hawaii, British Columbia, Northwest Territories, Nunavut, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador.

Callouts:

- Washington, Oregon, California, New York, Massachusetts, Pennsylvania, New Jersey, North Carolina, Mexico, Durango, Zacatecas, Jalisco, State of Mexico, Colombia, Brazil, Uruguay, Chile, Argentina, South Africa, Botswana, Senegal, Côte d'Ivoire, Gabon, Nigeria, Israel, Morocco, Iceland, Georgia, Kazakhstan, Turkey, Pakistan, China, Japan, Republic of Korea, Tokyo, Sakhalin, Lithuania, Latvia, Estonia, Czech Republic, Finland, Sweden, Norway, Denmark, Germany, Netherlands (Kingdom of the), Belgium, UK, Ireland, Luxembourg, Liechtenstein, France, Catalonia, Portugal, Spain, Italy, Switzerland, Austria, Slovenia, Hungary, Bosnia & Herzegovina, Albania, Montenegro, Greece, North Macedonia, Bulgaria, Serbia, Croatia, Romania, Moldova, Ukraine.
- British Columbia, Northwest Territories, Nunavut, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador.
- Hawaii.

Footnote:

(xlii) Instruments are considered "scheduled for implementation" once they have been formally adopted through legislation and have an official, planned start date. Instruments are considered "under consideration" if the government has announced its intention to work toward the implementation of a carbon pricing initiative and this has been formally confirmed by official government sources. Some countries that have mechanisms implemented also have additional instruments under consideration. For subnational jurisdictions only the subnational instrument is reflected.

Legend:

- Implemented
- Under Development

Implemented Mechanisms:

- Canada Federal GHG Offset System
- Washington Crediting Mechanism
- California Compliance Offset Program
- Mexico Crediting Mechanism
- Quebec Offset Crediting Mechanism
- Colombia Crediting Mechanism
- Chile Crediting Mechanism
- South Africa Crediting Mechanism
- UK Woodland Carbon Code
- Switzerland CO₂ Absorptions Crediting Mechanism
- Spain FES-CO₂ Program
- China GHG Voluntary Emission Reduction Program
- Vietnam Crediting Mechanism
- Thailand Voluntary Emission Reduction Program
- India Crediting Mechanism
- Sri Lanka Carbon Crediting Mechanism
- Indonesia Crediting Mechanism
- Indo-Pacific Carbon Offsets Scheme
- Australia Emissions Reduction Fund
- Republic of Korea Offset Credit Mechanism
- Sakhalin Oilseed Pilot Crediting Mechanism
- Joint Crediting Mechanism J-Cert Scheme
- Taiwan, China GHG Offset Management Program
- Beijing Parking Offset Crediting Mechanism
- Beijing Forestry Offset Mechanism
- Salvador Target Setting Emissions Trading System
- Salvador Forest Absorption Certification System
- Tokyo Cap-and-Trade Program
- Fujian Forestry Offset Crediting Mechanism
- Guangdong Pui Hui Offset Crediting Mechanism
- Chongqing Carbon Offset Mechanism

Under Development Mechanisms:

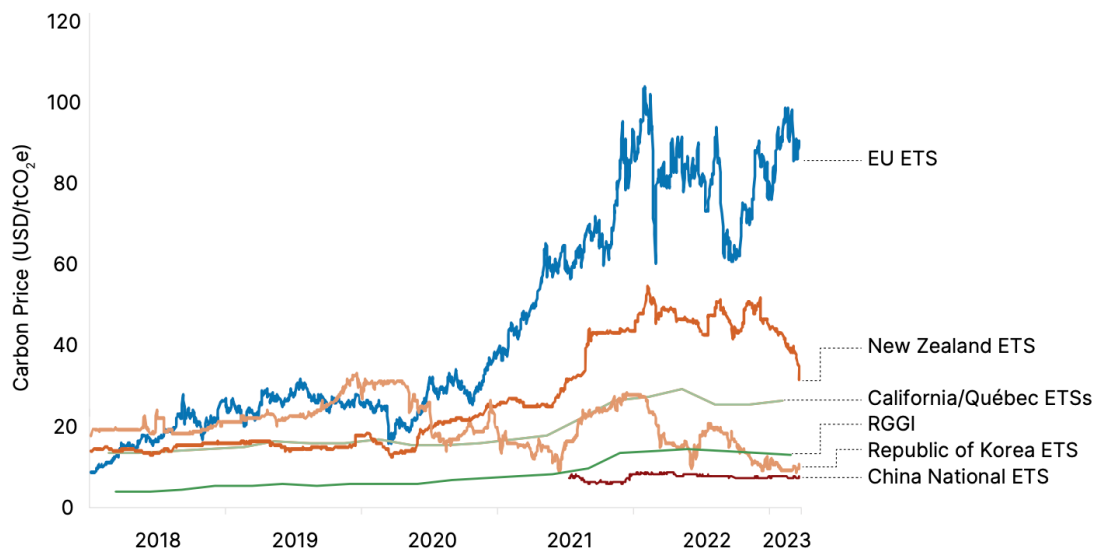
- Alberta Emission Offset System
- British Columbia Offset Program
- Saskatchewan GHG Offset Program
- Nova Scotia

² The World Bank, 2023. State and Trends of Carbon Pricing. Washington, DC: International Bank for Reconstruction and Development, The World Bank.

In terms of extent, ETS programs currently cover about 13% of global GHG emissions. But the share of emissions covered by emissions trading systems (ETS) around the world varies widely by jurisdiction. As of March 31st, 2023, the EU ETS covered roughly 38 percent of EU greenhouse gas emissions, or 1.5 gigatons (a billion and a half metric tons) carbon dioxide equivalent (1.5 GtCO₂-e).³ Meanwhile, the recently launched national ETS in China covered nearly 52 percent of the country's total GHG emissions, or roughly 7.5 GtCO₂-e. This makes it the largest carbon market in the world in terms of emissions covered. Other large markets include South Korea (0.580 GtCO₂-e), California (0.320 GtCO₂-e) and the UK (0.140 GtCO₂-e). The sectors covered by ETS differ among jurisdictions. For example, the China ETS and RGGI currently cover CO₂ emissions from their respective power sectors, while the EU ETS covers emissions from the power sector, domestic aviation, and industrial activities.

ETS and carbon tax revenues are rising, with an increase of about 10% between 2021 and 2022. Both sources now bring in about \$95 billion per year (USD). A large increase in carbon prices in the European market was responsible for most of that global increase. Current carbon prices in ETS and carbon tax schemes range from \$10 – \$83 tCO₂-e (Figure 3). According to Terrapass, the value of carbon offset credits sold in compliance markets was \$851 billion in 2021, a 164% increase from 2020.⁴ Further increases in carbon prices and the volume of offset credits purchased are expected due to increased demand and more stringent government regulations.

Figure 3: Carbon price evolution in select ETS from 2018 to 2023 (World Bank).



Voluntary offset credit markets

Individuals, universities, businesses, non-profits and even governmental agencies are increasingly using voluntary carbon markets to offset their GHG emissions in hopes of achieving a “net zero” status that can be reported to customers and investors. Protocols and standards related to the

³ Statista (2023). Estimated share of select jurisdiction’s GHG emissions covered by ETS. Available online at: <https://www.statista.com/statistics/1327131/ets-emissions-coverage-worldwide-by-country/>.

⁴ Terrapass, 2023. Overall Size of Carbon Offset Markets: How Big Are They? Available online [here](https://terrapass.org/carbon-offset-markets/).

supply, purchase, and trade of these credits are more like commodities subject to competition (i.e. various standard organizations compete to have their label used) rather than objective standards based on the science and economics of carbon accounting. The most ubiquitous standards for voluntary markets in the US are Verra's Verified Carbon Standard, the American Carbon Registry, the Climate Action Reserve, and Gold Standard.⁵

Voluntary carbon markets (VCMs) grew quite consistently through 2021 but had a significant downturn in 2022. In 2022, credit issuances totaled 279 million tons CO₂-e (279 Mt CO₂-e), down 21% from 2021 (379 Mt CO₂-e). Regardless, recent growth in value has been quite spectacular. The value of the VCM jumped from \$520 million in 2020 to \$2 billion in transactions in 2021. According to Ecosystem Marketplace, that jump was driven in large part by rising prices for credits, especially for nature-based credits for activities like reforestation, blue carbon from coastal and marine ecosystem projects, and avoided forest conversion.⁶ Credit prices continue to be well below compliance markets but are quite variable. In 2021 they ranged from a low of \$1.16 per metric ton CO₂ for transportation projects to \$5.80 for forestry and land use to \$8.81 for agriculture.

Quasi – public offset credit markets (a focus on REDD+)

International, national, state and local governments all spend money on environmental programs and some of this is allocated to projects that generate carbon credits that can be sold in either compliance or voluntary markets to generate public revenues or revenues for designated private or non-profit recipients. Unlike voluntary and compliance offset markets driven by private actors, quasi-public offsets are generated through public investments that may or may not generate credits that can be bought and sold in those markets but nonetheless in most cases represent payments for ecosystems services – including carbon storage or sequestration – provided directly to private or community forestland owners.

Credits generated by the UN's Reducing Emissions from Deforestation and Forest Degradation Plus Conservation (REDD+) is the most conspicuous example. Countries established the 'REDD+' framework to protect forests as part of the Paris Agreement. 'REDD' stands for reducing emissions from deforestation and forest degradation in developing countries. The '+' stands for additional forest-related activities that protect the climate, namely sustainable management of forests and the conservation and enhancement of forest carbon stocks. Under the framework with these REDD+ activities, developing countries can receive results-based payments for emission reductions when they reduce deforestation and sell the resulting offset credits generated. This serves as a major incentive for their efforts.

Created as a result of the United Nations Framework Convention on Climate Change in 2008, REDD+ is a transparent and accountable protocol for “generating market-tradable carbon offsets linked to activities that protect or enhance natural carbon sinks, and the

⁵ For convenience, links to standards and protocols can be accessed here for Verra's [Verified Carbon Standard](#), the [American Carbon Registry](#), the [Climate Action Reserve](#), and [Gold Standard](#).

⁶ Donofrio, S., Maguire, P., Daley, C., Calderon, C., Lin, K., 2022. The Art of Integrity. State of the Voluntary Carbon Markets 2022 Q3. Washington, DC: Ecosystem Marketplace.

communities and biodiversity that live within and around them”.⁷ Offset credits are issued under two categories:⁸

- Avoided planned deforestation (APD): These projects prevent large-scale conversion of primary forest by commercial agents. Commercial conversion activities can range from developing crop plantations to cattle ranches. These projects also protect the forest from secondary agents of deforestation, driven by subsistence-based practices.
- Avoided unplanned deforestation (AUD): These projects aim to protect forests from localized agents of deforestation, such as deforestation caused by local communities growing crops for local consumption or deforestation due to illegal logging.

To date, REDD+ has issued a total of 397 Mt CO₂-e in credits and is by far the largest source of credits from nature-based solutions. Transactions of REDD+ credits have grown 280% between September 2020 and September 2021. REDD+ credits typically trade higher than other nature-based solutions, and are currently around \$11 tCO₂-e. REDD+ credit demand is likely to surge in the next few years as REDD+ credits become more fully integrated into ETSs.

III: Market participants

Whittaker (2012) has completed one of the most exhaustive lists of key players in carbon markets. Key private sector actors include compliance participants, commercial banks, carbon funds, speculative investors, project developers and aggregators, consultants, equity research firms, carbon brokers, exchanges, credit rating agencies, and insurers.⁹ Key public sector actors include national governments, national business associations, and multilateral banks. For the purposes of this memorandum, and with an eye towards identifying field data needs where Adventure Scientists could play a role, here is a more parsimonious typology:

Regulators

For the most part, regulatory agencies play a role only in compliance offset credit markets. Regulatory agencies charged with overseeing ETS programs include such agencies as California’s Air Resources Board or China’s Ministry of Environment and Ecology. Regulators have a broad range of duties that include issuing rules and protocols related to emission reductions, allowances, offsets, resolution of disputes and penalties for non-compliance. Such agencies do engage in monitoring, but mostly around overall program effectiveness and not offset credit integrity.

⁷ UNFCCC has created a web-portal for REDD+, which can be accessed here: <https://redd.unfccc.int>.

⁸ Sylvera, 2023. The State of Carbon Credits 2022. Volume 1: Spotlight on REDD+. Available online at: <https://www.sylvera.com/resources/the-state-of-carbon-credits-report>.

⁹ Whittaker, M., 2012. Key Players in the Carbon Markets. Chapter 9 in Labatt, S., White, R.R., eds. Carbon Finance. Financial Implications of Climate Change. New York: John Wiley & Sons.

Project owners

These include investors and owners of physical assets that are used in offset credit generation, such as owners of forestland, farmland, energy facilities, transportation systems, waste disposal facilities, and industrial facilities. Some offset projects are owned by households (i.e. personal carbon credits) and community organizations. In California's offset credit market, Tesla is the leading source of carbon credits for sale.

Project developers and aggregators

Carbon project developers do the heavy lifting to get project owners into the market. Project developers retain a portion of the proceeds from the sale of carbon credits and pass on the rest to project owners. They carry out feasibility studies, draft project design documents, design field and desktop surveys to calculate emissions and carbon stock baselines, and establish a monitoring, reporting and verification process to ensure the integrity of credits over time. Aggregators are a particular form of project developer that pool together many small offset credit projects into a more economical package that lowers costs for everyone involved. Typically, credits involving natural climate solutions need thousands of acres to be economical. Anew, one of the leading developers in North America, asserts that 4,000 acres is the minimum viable size.¹⁰

Market intermediaries

An increasing number of carbon credits generated by owners and developers are purchased by intermediaries, which include brokers, retailers, or exchanges. The idea is to buy low and sell high when market conditions change. The presence of intermediaries has raised red flags over fraud, and their role is now under investigation. In 2022, an investigation noted that several brokers in the voluntary offset credit market are buying carbon credits from forestry projects in poorer nations and selling them at big margins. Likewise, an inquiry on SouthPole showed that the company was earning millions of dollars from brokering low-quality carbon credits.¹¹

Carbon registries

An offset registry is a system for reporting and tracking offset project information including project status, project documents, credits generated, ownership, sale, and retirement. Compliance offset programs must utilize a registry, and most REDD+ projects need to be registered to be eligible for financing. Carbon registries support carbon markets by tracking the ownership of offset projects, such as agricultural and forestry projects, and issuing offset credits for units of emission reductions or removal that have been verified and certified.¹² To avoid double-counting concerns, registries assign offset credits with serial numbers. If an entity, such as a covered emission source, submits the offset credit for compliance purposes or a company or individual claims a reduction in a voluntary market, the registry retires the serial number.

¹⁰ Visit Anew.com at <https://anewclimate.com/solutions/ncs>.

¹¹ Jennifer, L., 2023. Transparency in Intermediaries' VCM Transactions is Critical. Carbon Credits.com, February 7, 2023. Available online [here](#).

¹² Congressional Research Service, 2021. Agriculture and Forestry Offsets in Carbon Markets: Background and Selected Issues. Washington, DC: CRS.

Some carbon markets allow only offsets from certain carbon registries for use in their markets. For example, the Verra Registry, the American Carbon Registry, and Climate Action Reserve are approved registries in California’s cap-and-trade program, whereas The Gold Standard is not an approved registry for California’s program but is used by other programs. Verra is the largest carbon credit registry, accounting for nearly 40% of all credits globally.

Monitoring, reporting, and verification providers

Monitoring, reporting, and verification (MRV) is a critical function to ensure the integrity and accuracy of carbon credits. In compliance markets, MRV providers have to be accredited, a function performed by verification bodies. In the California ETS, a list of validation bodies is included as an example in Appendix A. Appendix B is a list of accredited validators. Any of these individuals or organizations could be potential clients or partners for Adventure Scientists.

Standards and protocol organizations

Perhaps the most important players in carbon markets are the organizations that issue standards and protocols that form the basis for credit generation. In compliance markets, registries often serve this role as well. The most ubiquitous standards in use for voluntary markets in the US are Verra’s Verified Carbon Standard, the American Carbon Registry, the Climate Action Reserve, and Gold Standard. REDD+ projects must adhere to one of seven standards, including UNFCCC REDD+ framework, FCPF Carbon Fund Program, Green Climate Fund’s REDD+ Result-based Payments Requests for Proposals Program, The REDD+ Environmental Excellence Standard (TREES), Tropical Forest Standard, Verra’s Jurisdictional Nested REDD+, and Verra’s Verified Carbon Standard.

Buyers

Carbon offset credit buyers in compliance markets are the regulated entities with emissions reduction requirements. In voluntary markets, it is any business or organization – including government entities - that is using offset credits to achieve its net zero commitments. The website Net Zero Tracker provides a useful database of net zero commitments of countries as well as the 2,000 largest publicly traded companies in the world.¹³

With offsets covering 16.6 Mt CO₂-e, the biggest buyer of carbon offset credits is the crypto trading company Toucan Protocol, according to Bloomberg. Toucan is a bridging protocol that turns real-life carbon credits into tokens that can be used on a blockchain. It was the first platform to allow for the tokenization of carbon credits. The other top carbon credit buyers in 2022 were Delta Airlines, Shell, and Volkswagen.¹⁴

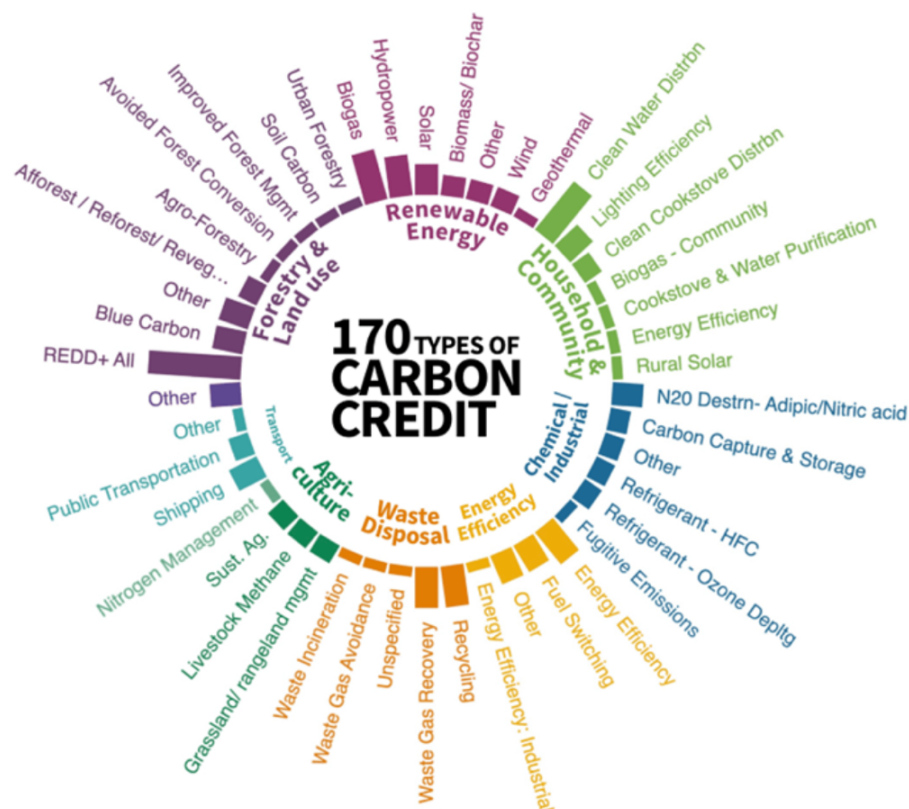
¹³ Access the Net Zero Tracker [here](#).

¹⁴ Jennifer, L., 2023. Who Issues Carbon Credits? (Everything You Need to Know). Carbon Credits.com, February 2, 2023. Available online [here](#).

IV: Typology of carbon credits issued

According to Ecosystem Marketplace, there were over 170 types of carbon credits transacted globally in 2022 (Figure 4).¹⁵ These have been grouped into nine major categories, including waste disposal, transport, forestry and land use, agriculture, renewable energy, household and community, renewable energy, chemical and industrial, and energy efficiency.

Figure 4: Typology of Carbon Credits Used by Ecosystem Marketplace



As noted above, in 2022, Climate Focus and others report that the volume of credits issued in the voluntary market was 279 MtCO₂-e.¹⁶ Credit issuances were dominated by wind, solar, and hydropower projects (35%) and nature-based solutions (33%) which include agriculture, forestry, and land use. REDD+ is by far the largest source of nature-based credits (75%), with improved forest management and afforestation as the next most abundant sources. In compliance markets, the volume of credit issuance is much less – estimated at about 43 MtCO₂-e in 2022 by the World Bank. Credit issuance here are dominated by forestry projects.¹⁷

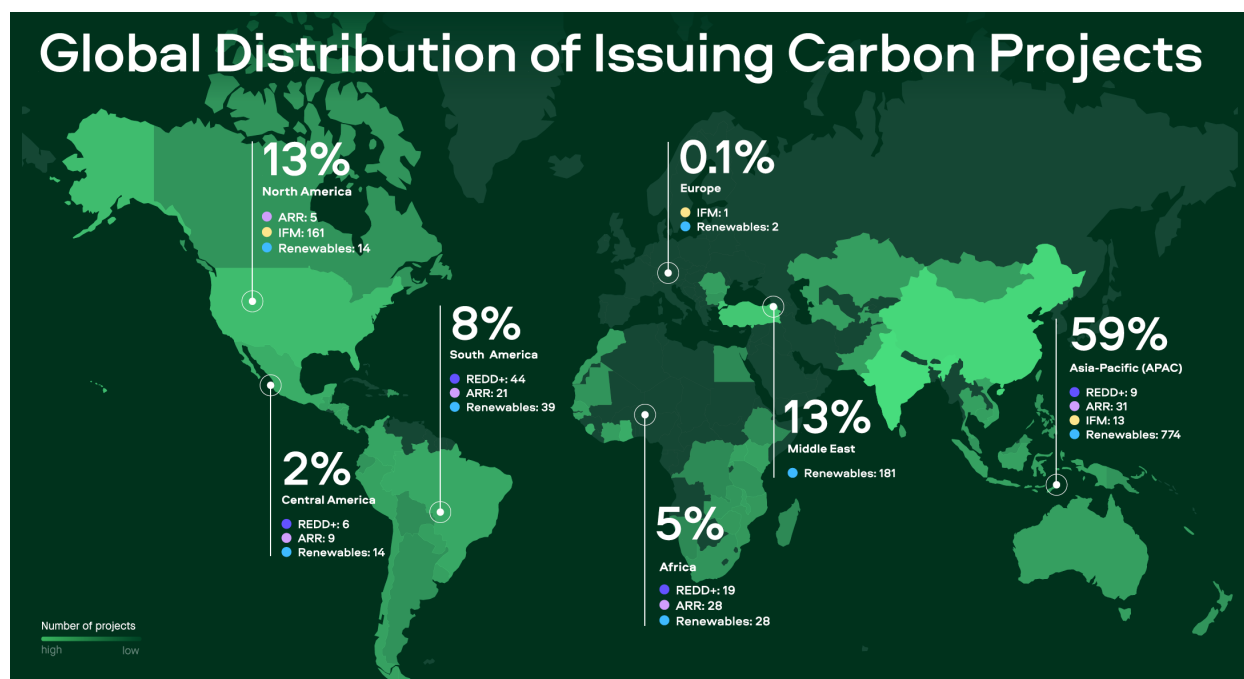
¹⁵ Forest Trends' Ecosystem Marketplace, 2022. The Art of Integrity. State of Voluntary Carbon Markets, Q3 Insights Briefing. Washington, DC: Forest Trends Association.

¹⁶ Climate Focus, 2022. Voluntary Carbon Market Overview. Available online at: <https://climatefocus.com/wp-content/uploads/2023/01/VCM-Dashboard-2022-Overview-1.pdf>.

¹⁷ For example, under California's cap and trade program, US forest projects thus far account for over 85% of all credits issued.

Sylvera, Inc. has created a useful graphic showing the global distribution of carbon credits issued through 2022 (Figure 5).¹⁸ Nearly 60% of global issuances were from Asia, and most of those took the form of renewable energy projects. North America accounts for the next largest share at 13%, with the majority of those credits generated by improved forest management.

Figure 5: Global Distribution of Carbon Credit Projects by Type



In the next memorandum, use of field data to generate these credits will be examined in detail. But there appear to be many opportunities for Adventure Scientists to play a role. For example:

- REDD+ projects often rely on citizen scientists to monitor and verify conditions on the ground since many of these projects are located in remote regions that are difficult to access and in places where traditional ecological knowledge needs to inform project design. Under these arrangements, known as “community based” or “locally based” forest monitoring, the community manages and implements the information collection process, with external professionals optionally providing planning and technical support.¹⁹ Professional support from Adventure Scientists here could involve training in field data collection methods and technologies – many that utilize smartphones and apps. Key

¹⁸ Sylvera, Inc., 2022. The State of Carbon Credits 2022. Available online at:

¹⁹ Fordham, S., Trivedi, M., Parker, C., Palmer Fry, B., 2021. Community Forest Monitoring and REDD+. How community forest monitoring can enable countries to achieve national and international REDD+ objectives. Oxford, UK: Global Canopy Programme. Available online at: <https://globalcanopy.org/wp-content/uploads/2021/03/Community-Forest-Monitoring-REDD.pdf>.

advantages of community monitoring are for improving the content and quality of the monitored information, and (ii) capacity-building towards community empowerment.²⁰

- Citizen scientists have been encouraged by the EPA and other agencies to provide independent verification of fugitive emissions from oil and gas infrastructure in part, to help verify reductions associated with methane capture projects. Activists on the Navajo Nation, for example, are using infrared cameras to detect leaks.²¹ The use of citizen monitoring is expected to drastically increase in response to an EPA program to allow third-party emissions tracking at methane leak sites.
- City Forest Credits (CFC) is the national standard for greenhouse gas emission reduction and removal for tree projects in cities and towns. Counties and cities are developing urban forest preservation and restoration projects to earn these credits and sell them to finance additional acquisitions, property management, and ecological restoration. King County, Washington recently completed the largest urban forest carbon credit project in history, bringing in over \$1 million for the County and its partners.²² Importantly, CFC protocols require periodic monitoring and reporting of forest growth, mortality, and canopy closure and encourage engagement of community members.²³ Adventure Scientists can certainly play a role in helping local governments meet these reporting requirements, which may include getting certified as a Validation and Verification Body (VVB).

V. Validity and integrity

Carbon offset credit markets are relatively new and evolving. As such, the integrity of carbon credits sold has often come into question. Systematic flaws have been uncovered and published rather extensively in the literature. Forest carbon credits are the most problematic. For example, with respect to forest carbon offsets in California, researchers provided direct evidence that comparing projects against coarse regional carbon averages has led to systematic over-crediting of 30.0 million tCO₂-e, or 29.4% of the credits they analyzed. These excess credits are worth an estimated \$410 million at recent market prices. They conclude that “[r]ather than improve forest management to store additional carbon, California’s forest offsets program creates incentives to generate offset credits that do not reflect real climate benefits.”²⁴

²⁰ McCall, M.K., Chutz, N., Skutsch, M., 2016. Moving from measuring, reporting, verification (MRV) of forest carbon to community mapping, measuring, monitoring. *PLoS ONE* 11(6): e0146038. doi:10.1371/journal.pone.0146038.

²¹ Hijazi, H., 2023. Methane Response Program Foreshadows ‘Hyper-Local’ Monitoring. *Bloomberg News*. 3-10-23. Available online at: <https://news.bloomberglaw.com/environment-and-energy/methane-response-program-foreshadows-hyper-local-monitoring>.

²² King County, WA, 2022. Three city forest preservation projects in King County contribute to the largest urban forest credit purchase in U.S. history – press release. Available online at: <https://kingcounty.gov/depts/dnrp/newsroom/newsreleases/2022/June/03-urban-forest-carbon-credits.aspx>.

²³ City Forest Credits has overall standards as well as protocols specific to afforestation and reforestation. They are available online at: <http://www.cityforestcredits.org/carbon-credits/carbon-protocols/>.

²⁴ Badgley, G., Freeman, J., Haman, J.J., Haya, B., Trugman, A.T., Anderegg, W.R.L., Cullenward, D., 2021. Systematic over-crediting in California’s forest carbon offsets program. *Glob Chang Biol.* 2022 Feb; 28(4): 1433-1445.

As another example, in an explosive investigative report conducted by The Guardian, Die Zeit and Source Material, researchers estimated that 94% of the rainforest offset credits sold by Verra are likely to be “phantom credits” and do not represent genuine carbon reductions.²⁵

To be valid, carbon offsets must meet several strict criteria, which have been succinctly summarized by Stockholm Environmental Institute and GHG Management Institute in their guide to use of carbon offsets.²⁶ These include:

- *Additionality* – projects must reduce or avoid GHG emissions relative to a business as usual baseline scenario. Many offset projects have been challenged because the project activities were probably going to occur anyway (i.e. cost-saving energy efficiency improvements) or because the presumed threats to forests or agricultural lands did not actually exist.
- *Permanence* – The reduction or avoidance of GHG emissions must be permanent, and not canceled by the future actions of current or future project owners.
- *Avoiding over-estimation* – The most conspicuous way GHG reductions can be overestimated is if a project’s baseline emissions are overestimated. Unfortunately, this is a relatively common occurrence.
- *Exclusivity* – Credits generated by an entity’s GHG emission reduction or avoidance activities must be the exclusive result of that entity’s actions.
- *Avoidance of social and environmental harm* – Rights of communities have not been violated and natural areas have not been converted into crops or tree plantations.
- *No leakage* – The reduction or avoidance of GHG emissions at a particular facility or parcel of land must not be canceled by an increase in GHG emissions by the same entity at another location.

SEI and GHG Management Institute have reviewed dozens of carbon offset credit projects and have grouped them into categories of risk associated with the violation of one or more of these criterion (Figure 6). Methane destruction, N₂O avoidance, and ozone depleting substances destruction are among credit projects with a low risk of violation, while the most common credit projects – agriculture, forestry, land use and renewable energy – are among projects with the highest risk.

But within these categories of projects with higher risk, there is also a range. For example, it is widely recognized that the most robust forestry sector credits are associated with avoided

²⁵ Greenfield, P., Weston P., 2023. Revealed: more than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows. The Guardian, 1-18-23, available online at: <https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoc>.

²⁶ Stockholm Environmental Institute and GHG Management Institute, 2019. Securing Climate Benefit: A Guide to Using Carbon Offsets. Available online at: https://www.offsetguide.org/wp-content/uploads/2020/03/Carbon-Offset-Guide_3122020.pdf.

deforestation, afforestation, and reforestation since these are the easiest to document and verify on the ground. REDD+ credits – mainly because of transparency and broad engagement of governments, NGOs, and communities are also generally considered of higher quality. For example, Sylvera, Inc., using a proprietary rating system for REDD+ credits, has found that “[a]lmost a third of the credits that Sylvera has assessed through our REDD+ carbon credits rating framework are considered high quality, with strong scores across the core pillars of carbon performance, additionality and permanence. As a result, these projects are considered low risk.”²⁷

Figure 6: SEI and GHG MI’s categorization of relative offset quality risk

Lower risk	Medium risk	Higher risk
<ul style="list-style-type: none"> • CO₂ usage • Methane destruction (w/o utilization) • N₂O avoidance from nitric acid production • N₂O – adipic acid* • Ozone-depleting substance (ODS) destruction 	<ul style="list-style-type: none"> • Methane capture and utilization • Methane avoidance • Energy distribution • Energy efficiency, household demand side • PFCs & SF₆ avoidance/ reuse • Renewable energy, small scale 	<ul style="list-style-type: none"> • Agriculture • Biomass energy • Cement production • Energy efficiency, industrial demand side • Energy efficiency -- supply side • Forestry & land use • Fossil fuel switching • Fugitive gas capture or avoidance • Low-carbon transportation measures • Renewable energy, large scale

This concludes a brief review of carbon offset credit markets in terms of their size, value, and trends, key participants, types of credits generated, and overall validity and integrity. The next memorandum will focus on the role of field data in credit issuance, best practices and technologies for field data gathering, and a drill down on some partnership opportunities for Adventure Scientists and its network of citizen scientists.

²⁷ Sylvera, Inc., 2023. What is the state of REDD+ carbon credits in 2022? Available online at: <https://www.sylvera.com/blog/redd-carbon-credits-2022>.

Appendix A: List of CARB-approved Verification Bodies

Accredited Verification Body (VB)	VB Street Address	VB City, State & Zip	VB Contact Person	VB Contact Email
Adelante Consulting, Inc.	430 W. Highway 6	Los Lunas, NM 87031	Virginia Smith	vsmith@adelanteconsulting.com
Agri-Waste Technology, Inc.	501 N. Salem Street, Suite 203	Apex, NC 27502	Hal Langenbach	hal@agriwaste.com
Analytical Environmental Services	1801 7th Street	Sacramento, CA 95811	Erin Quinn	eaquinn@montrose-env.com
Aster Global Environmental Solutions, Inc. (AGES)	3800 Clermont Street NW	North Lawrence, OH 44666	Shawn McMahon	smcmahon@asterglobal.com
Cameron-Cole, LLC.	50 Hegenberger Loop	Oakland, CA 94621	Chris Lawless	clawless@cameron-cole.com
Dillon Consulting Limited	235 Yorkland Boulevard, Suite 800	Toronto, ON M2J 4Y8 (Canada)	Jack Wallace	jwallace@dillon.ca
Environmental Services, Inc.	7220 Financial Way, Suite 100	Jacksonville, FL 32256	Shawn McMahon	smcmahon@esinc.cc
First Environment of California, Inc.	770 L Street, Suite 950	Sacramento, CA 95814	Jay Wintergreen	jtw@firstenvironment.com
GHD Services, Inc.	5900 Hollis Street, Suite A	Emeryville, CA 94608	Valerie Chan	Valerie.Chan@ghd.com
NSF Certification, LLC	789 N. Dixboro Road	Ann Arbor, MI 48105	John Shideler	shideler@nsf.org
Ruby Canyon Environmental, Inc.	743 Horizon Court, Suite 385	Grand Junction, CO 81506	Zach Eyler	zeyler@rubycanyonenv.com
S&A Carbon, LLC	705 SE 55th Ave	Portland, OR 97215	Kyle Silon	kyle.silon@saacarbon.com
SCS Engineers	3900 Kilroy Airport Way, Suite 100	Long Beach, CA 90806	Raymond Huff	RHuff@scsengineers.com
SCS Global Services	2000 Powell Street, Suite 600	Emeryville, CA 94608	Zane Haxtema	zhaxtema@scsglobalservices.com
SES, Inc.	10901 West 84th Terrace, Suite 175	Lenexa, KS 66214	Patrick Splichal	psplichal@ses-corp.com
Trinity Consultants, Inc.	20 Corporate Park, Suite 200	Irvine, CA 92606	Charles C. Lee	clee@trinityconsultants.com

Appendix B: List of CARB approved Verifiers

Executive Order	Last Name	First Name	Employer / Affiliation	Office Phone	Email Address
H2-20-237	Addison	Randall	NCRM, Inc.	707-485-7211	Rladdison@outlook.com
H2-19-208	Andrews	Mallory	Cameron-Cole, LLC	510-777-1874	mandrews@cameron-cole.com
H2-18-219	Bayne	Ryan	GHD Services, Inc.	517-230-0741	Ryan.Bayne@ghd.com
H2-19-176	Boss	Brent	Dillon Consulting Limited	780-907-4997	bboss@dillon.ca
H2-18-225	Brown	Letitia (Letty) B.	SCS Global Services	510-452-9098	LBBrown@scsglobalservices.com
H2-19-117	Carim	Michael M.	First Environment, Inc.	626-529-3089	mic@firstenvironment.com
H2-18-218	Chan	Valerie	GHD Services, Inc.	519-884-0510	Valerie.chan@ghd.com
H2-18-216	Chapman	Dwight	Southwest Research	530-739-3060	dwight@southwest-research.com
H2-19-231	Clarke	Jason	GHD Services, Inc.	510-385-0601	jason.clarke@ghd.com
H2-19-125	Cote	Michael	Ruby Canyon Environmental, Inc.	970-241-9298 x11	mcote@rubycanyonenv.com
H2-19-113	Crews	Bonny	Ruby Canyon Environmental, Inc.	972-241-9298	bcrews@rubycanyonenv.com
H2-20-186	Cunningham	Phillip	Ruby Canyon Environmental, Inc.	970-241-9298	pcunningham@rubycanyonenv.com
H2-19-234	Cwiklik	James	SCS Global Services	510-452-9092	jcwiklik@scsglobalservices.com
H2-19-200	Daley	Jeff	First Environment, Inc.	630-299-3190	jjd@firstenvironment.com
H2-19-155	DeBusschere	Michael T.	NSF Certification, LLC	502-451-9821	mdebussche@nsf.org
H2-19-229	DeLong	Haley	SCS Engineers	707-236-3788	hdelong@scsengineers.com
H2-18-217	DeMars	Anthony Richard	GHD Services, Inc.	612-524-6868	Tony.demars@ghd.com
H2-19-110	Dobson	Rob	SES, Inc.	434-202-0532	rdobson@ses-corp.com
H2-19-123	Drotman	Cassandra	SCS Engineers	562-637-4486	cdrotman@scsengineers.com
H2-19-168	Eaton	Francis	SCS Global Services	510-452-8000	featon@scsglobalservices.com
H2-20-194	Eggleton	Andrea Hardlund	FRST Corp	530-615-4067	aheggleton@firstcorp.com
H2-18-220	Eggleton	JR Christian	FRST Corp	530-615-4067	ceggleton@firstcorp.com
H2-19-116	Eyler	Zach	Ruby Canyon Environmental, Inc.	970-241-9298 x15	zeyler@rubycanyonenv.com
H2-20-248	Facemire	Timothy	FRST Corp	530-615-4067	tfacemire@firstcorp.com
H2-20-184	Fiouzian	Mani	South Coast Air Quality Management District	909-396-2417	mfiouzian@aqmd.gov
H2-19-233	Fremming	Michelle	Cameron-Cole, LLC	510-777-1872	mfremming@cameron-cole.com
H2-21-249	Gerber	Benjamin	GHD Services, Inc.	519-340-4354	Ben.Gerber@ghd.com
H2-19-166	Hampton	Haydee	Western Spatial Solutions LLC	928-380-2551	HHampton@WesternSpatialSolutions.com
H2-19-131	Haxtema	Zane Andrew	SCS Global Services	510-292-5968	zhaxtema@scsglobalservices.com
H2-20-159	Henderson	Lawson	S&A Carbon, LLC	(none)	lawson.henderson@saacarbon.com
H2-19-141	Henkelman	John	SCS Engineers	916-503-2955	jhenkelman@scsengineers.com
H2-19-210	Hirst	Michelle	Engenicom	+61 (0)492 803 356	m.hirst@engenicom.com.au
H2-19-232	Hoe	Michael	SCS Global Services	541-231-6756	MHoe@SCSglobalservices.com
H2-19-167	Hohl	Aaron	SCS Global Services	614-623-9030	amhohl@yahoo.com
H2-18-222	Holley	Aaron M.	Environmental Services, Inc.	681-285-5371	aholley@esinc.cc
H2-20-242	Huff	Raymond	SCS Engineers	562-637-4561	RHuff@scsengineers.com
H2-18-221	Jaeschke	Eric M.	Environmental Services, Inc.	703-314-9064	ejaeschke@esinc.cc
H2-18-224	Kandaris	Alexa E.	S&A Carbon, LLC	541-531-1368	alexa.kandaris@saacarbon.com
H2-19-138	Krupinsky	Henry	Cameron-Cole, LLC	510-777-1859	dkrupinsky@cameron-cole.com
H2-20-240	LaGreca	David	Ruby Canyon Environmental, Inc.	970-368-0540	dlaGreca@rubycanyonenv.com
H2-19-104	Langenbach	Hal	Agri-Waste Technology, Inc.	919-367-6312	hal@agriwaste.com
H2-19-108	Lawless	Christopher	Cameron-Cole, LLC	510-777-1858	clawless@cameron-cole.com
H2-20-243	Le	Camille	SCS Engineers	562-426-9544	Cle@scsengineers.com
H2-20-181	Lee	Charles C.	Trinity Consultants Inc.	949-567-9880 x102	clee@trinityconsultants.com
H2-20-245	Liu	Cheng-ying (Alex)	GHD Services, Inc.	949-585-5249	Alex.liu@ghd.com
H2-18-223	Lutes	Matthew	NSF Certification, LLC	530-242-4228	mlutes@nsf.org
H2-20-170	Lutz	Mark	NSF Certification, LLC	209-581-3733	lutz@QualitySystems.org
H2-20-191	Mattson	Kim	Ecosystems Northwest / Mattson and Mattson	530-925-5943	Mattson@EcosystemsNW.com
H2-19-230	McGrath	Jonathan	LandVest, Inc.	803-399-7844	jmcgrath@landvest.com
H2-19-164	McMahon	Shawn	Environmental Services, Inc.	330-294-1242	smcmahon@esinc.cc
H2-19-235	Morgan	Robert	Dillon Consulting Limited	519-571-9833 x3156	rmorgan@dillon.com
H2-19-205	Mosley	Christopher Thomas	Agri-Waste Technology, Inc.	919-367-6311	cmosley@agriwaste.com
H2-19-178	Nagulapaty	Subbarao V.	GHD Services, Inc.	510-420-3361	subbarao.nagulapaty@ghd.com
H2-20-247	Nasir	Filzah	GHD Services, Inc.	519-340-4231	filzah.nasir@ghd.com
H2-19-204	Nencetti	Luca	First Environment, Inc.	973-334-0003	lnencetti@firstenvironment.com
H2-20-187	Perkowski	Matthew	Aster Global Environmental Solutions, Inc.	330-294-1242	mperkowski@asterglobal.com
H2-19-130	Pinette	Nina	Ruby Canyon Environmental, Inc.	970-241-9298 x14	npinette@rubycanyonenv.com
H2-20-185	Phan	Tony	Trinity Consultants Inc.	661-282-2200	tphan@trinityconsultants.com
H2-19-112	Pollet-Young	Christie	SCS Global Services	510-452-9093	cpollet-young@scsglobalservices.com
H2-20-188	Pomp	Jonathan	New Conservation, LLC	604-642-1277	jpomp@new-conservation.com
H2-19-203	Pope	Jennifer	Adelante Consulting, Inc.	505-920-4739	jpope@adelanteconsulting.com
H2-19-133	Quinn	Erin Arturo	Analytical Environmental Services	916-402-7523	eaquinn@montrose-env.com
H2-19-212	Reed	Pablo	S&A Carbon, LLC	203-824-7733	pablreed@gmail.com
H2-20-246	Romzick	Peter	GHD Services, Inc.	248-893-3422	Pete.Romzick@ghd.com
H2-20-239	Saini	Ishwar	Macquarie Energy, LLC	713-275-6818	ishwar.saini@macquarie.com
H2-21-137	Sellers	Caitlin	Aster Global Environmental Solutions, Inc.	330-294-1242 x107	csellers@asterglobal.com
H2-19-118	Sentner	Tina	Pele Consulting Services, Inc.	951-427-0333	tina@peleconsultingservices.com
H2-20-244	Sexton	Travis	Agri-Waste Technology, Inc.	919-367-6309	tsexton@agriwaste.com
H2-19-145	Shideler	John	NSF Certification, LLC	734-913-5797	shideler@nsf.org
H2-18-227	Silon	Kyle	S&A Carbon, LLC	971-235-7835	Kyle.silon@saacarbon.com
H2-19-214	Singleton	Edwin J.	(none)	505-856-5573	esingleton69@yahoo.com
H2-19-236	Skees-Gregory	Dresden	NSF Certification, LLC	503-645-1202	Dresden@nwsustainable.net
H2-19-209	Smith	Virginia	Adelante Consulting, Inc.	505-920-4150	vsmith@adelanteconsulting.com
H2-19-143	Splichal	Patrick	SES, Inc.	913-307-0046 x16	psplichal@ses-corp.com
H2-19-211	Stack	Bill	S&A Carbon, LLC	802-436-1960	bill.stack@saacarbon.com
H2-20-241	Stavole-Carter	Jessica	Ruby Canyon Environmental, Inc.	970-241-9298 x17	jstavole@rubycanyonenv.com
H2-18-226	Thurmes	John	True North Forestry LLC	(none)	thurmes.forestry@gmail.com
H2-19-198	Toole O'Neil	Barbara	(none)	650-296-9960	bttooleoneil@gmail.com
H2-20-238	Townsend	David	Townsend Environmental Consulting, LLC	816-392-2056	dtownsendilc@gmail.com
H2-18-228	Tuffly	Dr. Michael	ERIA Consultants, LLC	303-449-5146	mtuffly@eriaconsultants.com
H2-19-160	Turner	Robert J.	S&A Carbon, LLC	802-453-2171	robert.turner@saacarbon.com
H2-19-213	Wallace	Jack	Dillon Consulting Limited	403-215-8880 x4364	jwallace@dillon.ca
H2-19-115	Walters	David K.	Green Diamond Resource Company	206-224-5826	Dave.walters@greendiamond.com
H2-19-215	Weber	Catharine	SES, Inc.	913-307-0046 x14	cweber@ses-corp.com
H2-19-165	Wilson	Trenton	Analytical Environmental Services	916-447-3479	twilson@analyticalcorp.com
H2-19-121	Wintergreen	James	First Environment, Inc.	916-492-6080	jtw@firstenvironment.com
H2-19-196	Zehr	Zachary	Dillon Consulting Limited	519-571-9833	zzehr@dillon.ca