CHAPTER 16

Carbon Deposits—Using Soil and Blockchains to Achieve Net-Zero Emissions

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16.1 Carbon Deposit: An Innovative Concept

The carbon deposit is an innovative concept for carbon finance that leverages the power of soils to sequester carbon and achieve net-zero emissions of the greenhouse gases (GHGs) driving climate change. The *carbon-deposit system* acts like a carbon tax on the front end, but uses the funds raised to pay farmers and ranchers on an equal ton-for-ton basis to put the carbon back in the soil where it belongs to. Blockchain technology provides transparent accounting for the system with smart contracts that link a carbon dioxide source directly to a soil carbon sink that sequesters an equal amount of carbon into the soil.

The carbon deposit plan combines two popular policy proposals: the French Ministry of Agriculture's "*4 per 1000*" proposal, which seeks to improve soil carbon stocks by 0.4% per year; and a US$40 per ton carbon tax on CO_2 emissions proposed by the US-based Climate Leadership Council (CLC). But unlike the CLC's tax proposal which would pay the funds out as dividends to citizens, in the carbon-deposit system the funds collected would be paid to farmers to deposit carbon in the soil where it provides cascading environmental benefits. The dollars follow the molecules: US$40 per ton of CO_2 collected on emissions, translates to US$150 per ton of carbon that is paid to farmers to practice restorative agriculture and build up healthy soil. A small portion of the funds would be used to pay for monitoring, reporting, and verification systems (MRV). The CLC estimates the CO_2 tax could reduce CO_2 emissions by 25%−30%;[1] whereas, the French Ministry of Agriculture argues that soil carbon sequestration could absorb the remaining 75% of CO_2 emissions.[2] In theory, the combination of these two measures will result in net-zero emissions and a balanced carbon cycle.

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1 Climate Leadership Council. (2017). *A winning trade*. Retrieved from https://www.clcouncil.org/wp-content/uploads/2017/02/A_Winning_Trade.pdf.

2 French Ministry of Agriculture. (2015). Retrieved from https://www.4p1000.org/.

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Blockchain provides an effective technology platform for the accounting of this complex system. Blockchains track an asset through its lifecycle via a shared and open ledger whose contents cannot be altered but can be read by all participants. In this system, the asset is 1 ton of carbon, tracked on a Blockchain from its emission source to its sequestration sink. Auditors and regulators who certify both the emissions and sequestration would also be registered on the immutable Blockchain, which can be transparently audited.

16.2 Soil Carbon Sequestration

Carbon dioxide is the primary GHG accumulating in the atmosphere. According to the United Nations—Intergovernmental Panel on Climate Change (UN IPCC), anthropogenic GHG emissions are around 36 billion tons of CO_2 which equals 9.8 billion tons, or metric gigatons (Gt) of carbon per year.[3] Most of these emissions come from fossil fuel combustion, though a little more than one Gt are emitted from land-use changes. Of the 9.8 Gt of carbon in the atmosphere, approximately 3.2 Gt are absorbed by plants through photosynthesis, whereas approximately 2.3 Gt are absorbed by the oceans, leaving a net accumulation in the atmosphere of around 4.3 Gt of carbon per year.

The Earth's soils contain around 2400 Gt of carbon, three times the 750 Gt found in the atmosphere. The natural terrestrial carbon cycle of plant respiration and decomposition exhales carbon, whereas plant photosynthesis absorbs carbon, cycling around 120 Gt up and down annually. Likewise, the ocean's natural carbon cycle of air-sea gas exchange is around 90 Gt up and down annually. The Earth's natural carbon cycles dwarf the anthropogenic carbon emissions that are driving climate change. Human carbon emissions of less than 10 Gt are large enough to push the natural carbon cycles out of balance causing climate change; however, they are a fraction of the natural carbon cycles and can be brought back into balance.

According to the Food and Agriculture Organization of the United Nations (UN FAO), there are 4.9 billion hectares of agricultural land potentially available for carbon farming, including 1.54 billion hectares of planted crop lands and 3.36 of pasture and grasslands.[4] This is equal to 12.1 billion acres globally (1 hectare = 2.47 acres); this does not include another 4.03 billion hectares of global forests. Science and common sense farming both show us that practices that increase soil carbon also improve soil health in general, leading to improved water retention, soil microbiology, fertility, and productivity. The measure of soil carbon can be used as a proxy for soil health, generally speaking, more soil carbon

[3] IPCC. (2014). *Climate change 2014: Synthesis report*. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri, & Meyer, L.A. (Eds.)]. Geneva, Switzerland: IPCC, 151 pp.

[4] UN FAO. (2015). *World agriculture: Towards 2015/2030. An FAO perspective…* Retrieved from http://www.fao.org/docrep/005/y4252e/y4252e06.htm.

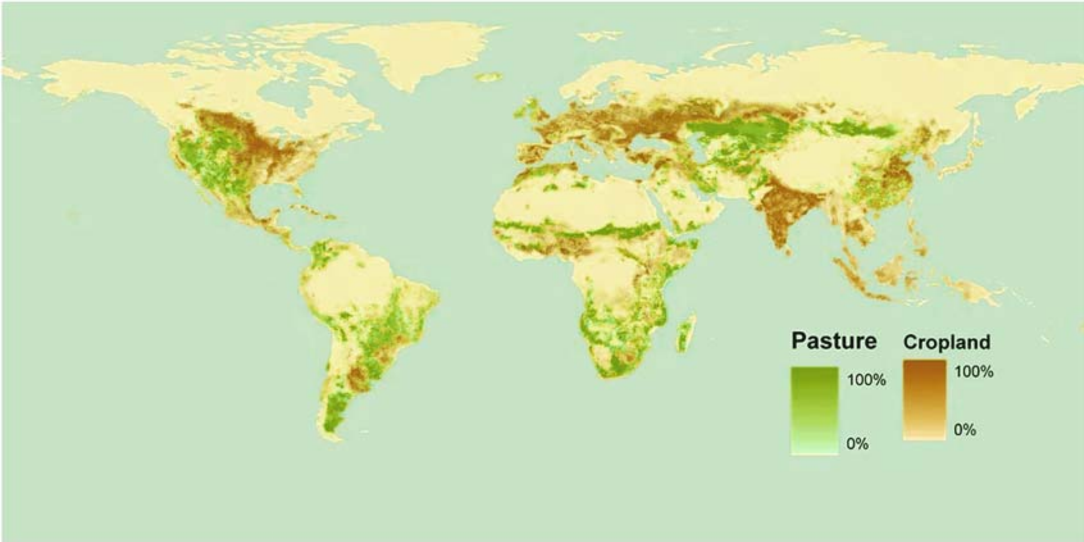


Figure 16.1
A world map of cropland and pastureland available for regenerative agriculture. *Source: Image data derived from UN FAO. (2015). World agriculture: Towards 2015/2030. An FAO perspective. Retrieved from http://www.fao.org/docrep/005/y4252e/y4252e06.htm.*

means better soil health. Research into restorative agriculture has shown consistently on small scales that it is possible to sequester a ton of carbon per hectare per year, and in practice rates range from ¼ to 20 + tons per hectare. Soil science indicates that global sequestration capacity ranges from 3 to 8 Gt per year.[5] Using 1 ton of carbon sequestration per hectare as a benchmark, spread across 4.9 billion hectares, it is reasonable to target net-zero emissions if global society can also bring emissions down by 25%–30% to manageable levels (Fig. 16.1).

16.3 Carbon-Deposit Payment to Farmers

In order to pay farmers to sequester carbon, effective systems for MRV emission reductions need to be established. These could be paid for by setting aside a small percentage of the funds raised as system overhead. An allocation of, for example, 0.25% could generate over a billion dollars for monitoring and verification. Mathematically, at US$150 per ton of carbon (roughly US$40 per ton of CO_2), a global program that covers 4.3 billion tons of carbon emissions would yield a fund of US$645 billion with US$1.6 billion available for monitoring and verification. US$645 billion directed into global agriculture would be a major new source of revenues in the US$5 trillion global agriculture market. These funds

[5] Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, P., Smith, P. (2016). Climate smart soils, *Nature*, 532.

would flow from industrial and urban areas of high emissions to rural areas where carbon farming was practiced, and under international agreements, could flow from the industrial north to the developing south.

Before we discuss how Blockchain will support the carbon-deposit, MRV, and payment systems, it is worth for us to understand better how soil absorbs carbon from the perspective of agricultural science.

16.4 Agricultural Practices and Soil Health

Plants use carbon dioxide for food and absorb it through photosynthesis during which the CO_2 molecule is broken down and the oxygen atoms are released. The carbon is converted into carbohydrates, some of which are used for plant growth, although the rest are directed down through the roots into the soil where bacteria and mycorrhizal fungi convert the carbon into stable forms of soil, such as humus, where it remains effectively sequestered. The amounts of carbon in soil, along with the vitality of the soil microbiology, are key indicators of soil health and productivity.[6] Industrialized farming techniques have generally focused on productivity alone and not on soil health. In fact, these practices often leave soils depleted of their vitality. Farm practices that leave soil bare and exposed lead to losses of soil carbon through erosion and oxidation to the atmosphere. Other farm practices such as the heavy use of nitrogen fertilizers, herbicides, and pesticides can also have a deleterious effect on soil health by breaking up the delicate web of bacterial and fungal biology. Healthy soils are dark, moist, and rich, rather than pale, hard, and dry. Healthy soils absorb water more effectively than depleted soils, allowing them to weather floods and droughts better than hard packed soils in which water runs across the top of instead of soaking in.

The practice of restorative agriculture places soil health as a central concern alongside crop productivity. The primary practices consist of minimizing (or completely eliminating) tilling, while also using cover crops so that the soil is never left bare. Other practices such as the spreading of manure and compost add carbon to the soil, but, more importantly, stimulate the growth of bacteria and fungi. Some rotational and cover crops, such as legumes, are good at fixing nitrogen in the soil and allow farmers to minimize the use of synthetic nitrogen fertilizers.

Estimates of global soil sequestration capacity vary among soil scientists. Dr. Rattan Lal from the Ohio State University estimates the global sequestration capacity at around 3.8 Gt per year.[7] Other scientists such as Dr Johannes Lehmann from Cornell University take a more expansive view and estimate that global soils could absorb as much as 8 Gt per

6 Lal, R. (2014). Societal value of soil carbon, *Journal of Soil and Water Conservation*, 69(6).

7 Lal, R. (2010). Managing soils and ecosystems for mitigating anthropogenic carbon emissions and advancing global food security, *BioScience*, 60(9), 708−721.

year.[8] Experts such as Eric Toensmeier estimate that sequestration rates per acre can vary from ¼ to 10 tons per acre and more.[9]

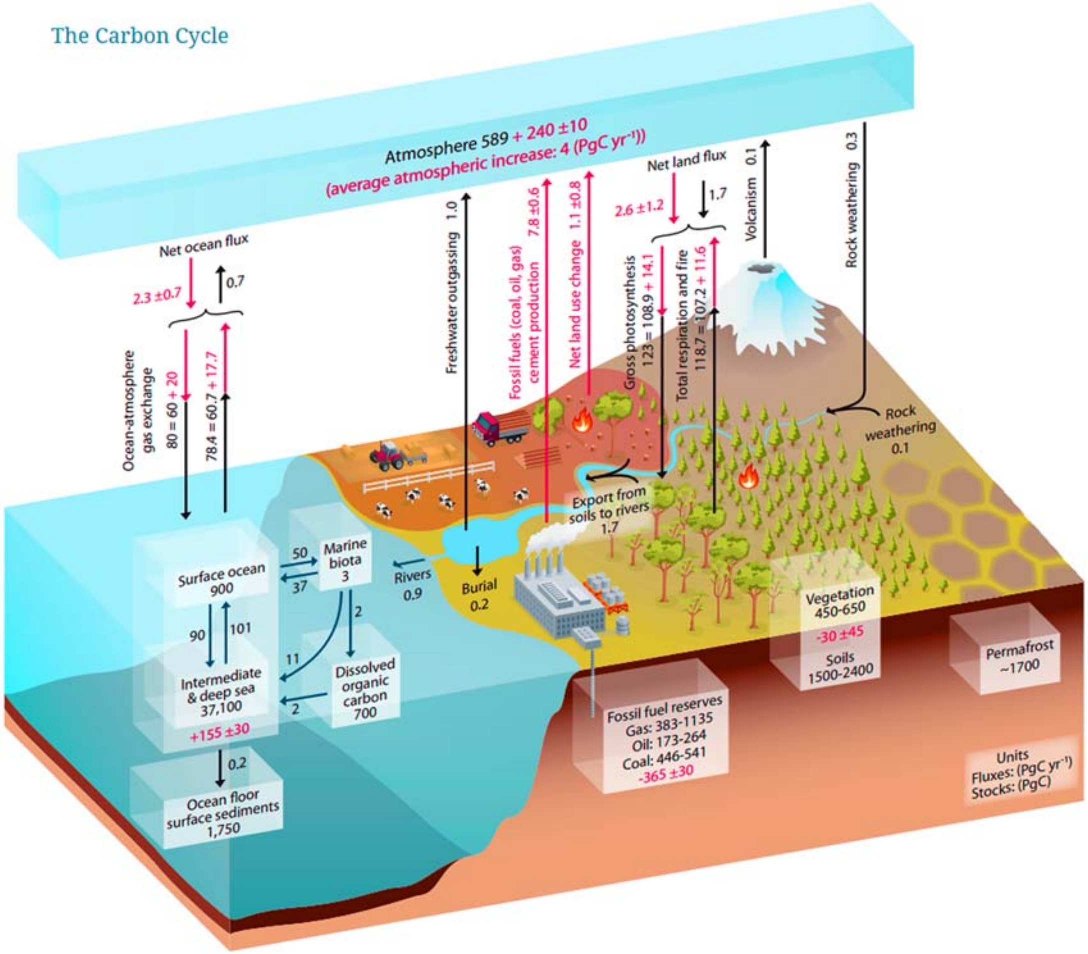
Much of the discrepancy among scientists results from differences in how deep the soil carbon is measured. Soil science research often focuses on topsoil (i.e., the top 15−30 cm), but many plants have root systems that extend down 2 m or more. The deeper the root system, the farther down the carbon can be deposited. From a carbon farming perspective, deeper root systems are better because they expand the overall soil sequestration capacity. Sequestration rates on any given parcel of land will vary over time and can eventually saturate, it is a highly dynamic system. New deep-rooted crop varieties could be developed that are intended to sequester as much carbon as possible. For the purposes of measuring carbon sequestration and carbon farming, it would be important to conduct deep soil measurements.

The Rodale Institute, an organic farming research institute, has conducted decades of farm systems trials which compare conventional farming techniques with regenerative organic farming techniques side-by-side. In a 2014 paper,[10] Rodale Institute claimed that "on-farm soil carbon sequestration can potentially sequester all of our current annual global GHG emissions of roughly 52 $GtCO_2e$." In 2003, Rodale published experiment results that showed their techniques were consistently able to sequester 0.5 tCO_2 annually in the top 1 foot (30 cm) of soil per acre. In addition to increasing soil carbon from 15% to 28%, soil nitrogen was also increased from 8% to 15% resulting in increased soil microbial activity, and specifically mycorrhizal fungi, which plays a key role in beneficial soil carbon cycles[11] (Fig. 16.2).

16.5 Policy Proposals

As foreshadowed at the beginning of this chapter, there are two major climate policy proposals that were combined to provide the mathematical foundation for the carbon-deposit concept. The French Ministry of Agriculture was the first governmental organization to embrace regenerative agriculture as a climate change solution at the COP21 meetings in 2015. The CLC in the United States is a private group promoting a carbon tax, the group includes leading conservative politicians as well major fossil fuel firms like

8 Lehmann, J., & Kleber, M. (2015). The contentious nature of soil organic matter, *Nature*, 528(7580), 60−68.
9 Toensmeier, E. (2016). *The carbon farming solution.* White River Junction, VT: Chelsea Green Publishing.
10 Rodale Institute. (2014). *Regenerative organic agriculture and climate change: A down-to-earth solution to global warming.* Retrieved from https://rodaleinstitute.org/assets/WhitePaper.pdf.
11 Rodale Institute. (2003). *Organic agriculture yields new weapon against global warming: Groundbreaking study proves organic farming counters greenhouse gases.* Retrieved from http://www.strauscom.com/rodale-release/.



The numbers represent carbon reservoirs in Petagrams of Carbon (PgC; 10^{15}gC) and the annual exchanges in PgC/year. The black numbers and arrows show the pre-Industrial reservoirs and fluxes. The red numbers and arrows show the additional fluxes caused by humans averaged over 2000-2009, which include emissions due to the burning of fossil fuels, cement production and land use change (in total about 9 PgC/year). Some of this additional anthropogenic carbon is taken up by the land and the ocean (about 5 PgC/year) while the remainder is left in the atmosphere (4 PgC/year), causing rising atmospheric concentrations of CO_2. The red numbers in the reservoirs show the cumulative changes in anthropogenic carbon from 1750-2011; a positive change indicates that the reservoir has gained carbon.

Figure 16.2
The global carbon cycle and the scale of planetary carbon sinks.

ExxonMobil who have historically opposed climate change policy, illustrating the shifting political winds and broad based support for the proposal.

The French Ministry of Agriculture's "4 per 1000" proposal is intended to promote the use of soil as a carbon sink in the fight against climate change. "4 per 1000" refers to increasing soil carbon content by 0.4% per year compounded annually. In this model, soil carbon measured down to a depth of 30 cm (approximately 1 ft) equals around 700 Gt. Increasing this topsoil content by 0.4% annually would equal 2.8 Gt carbon drawn down every year. Measuring soil carbon down to 2 m yields 2400 Gt. Increasing that count by 0.4% per year would be a drawdown of 9.6 Gt per year, which is more than enough to offset anthropogenic emissions completely (Fig. 16.3).

The CLC's proposal centers on a carbon tax of US$40 per ton combined with dividend payments to citizens, so that all the money that is raised by the carbon tax is paid back directly to the public. The purpose of the dividend payments is to both help citizens afford the higher energy costs, whereas also avoiding disputes over alternative uses for the funds. The proposal has met with wide acceptance across the political spectrum and is significant for including the endorsements of major fossil fuel firms, who have at times resisted taking action on carbon emissions and climate change. This plan is laudable for its intentions to be equitable and fair; however, it does not go far enough to completely solve the emissions problem.

The CLC's carbon tax is estimated to be able to reduce emissions by 25%–30%,[12] primarily from the electric power sector, where coal is readily replaced by natural gas, renewables, and nuclear power. Emissions from heavy-duty transportation (e.g., ships, planes, and trains) and energy-intensive industry remain steady because fuel switching options are limited and fuel price sensitivity is inelastic. This explains why soil sequestration is so important, it is the only option that can cost-effectively soak up carbon emissions on a global scale. Even as efficiency measures and electric vehicles used for light duty transportation work to eliminate some carbon emissions, other sectors of industry are already highly optimized and have little or no options to move away from hydrocarbon fuels. High temperature manufacturing, such as for concrete and steel, requires fuels, not electricity. Likewise, the superior energy density of liquid fuels over batteries ensures that some form of carbon-based fuels will continue to dominate military, aviation, maritime, mining, and other heavy-duty transport sectors.

Using the funds raised from the carbon tax to pay farmers and ranchers for carbon farming is logical as it offers favorable economics, environmental and emission reduction benefits, and can ultimately result in a global solution for net-zero emissions (Fig. 16.4).

[12] Climate Leadership Council. (2017). *A winning trade*. Retrieved from https://www.clcouncil.org/wp-content/uploads/2017/02/A_Winning_Trade.pdf.

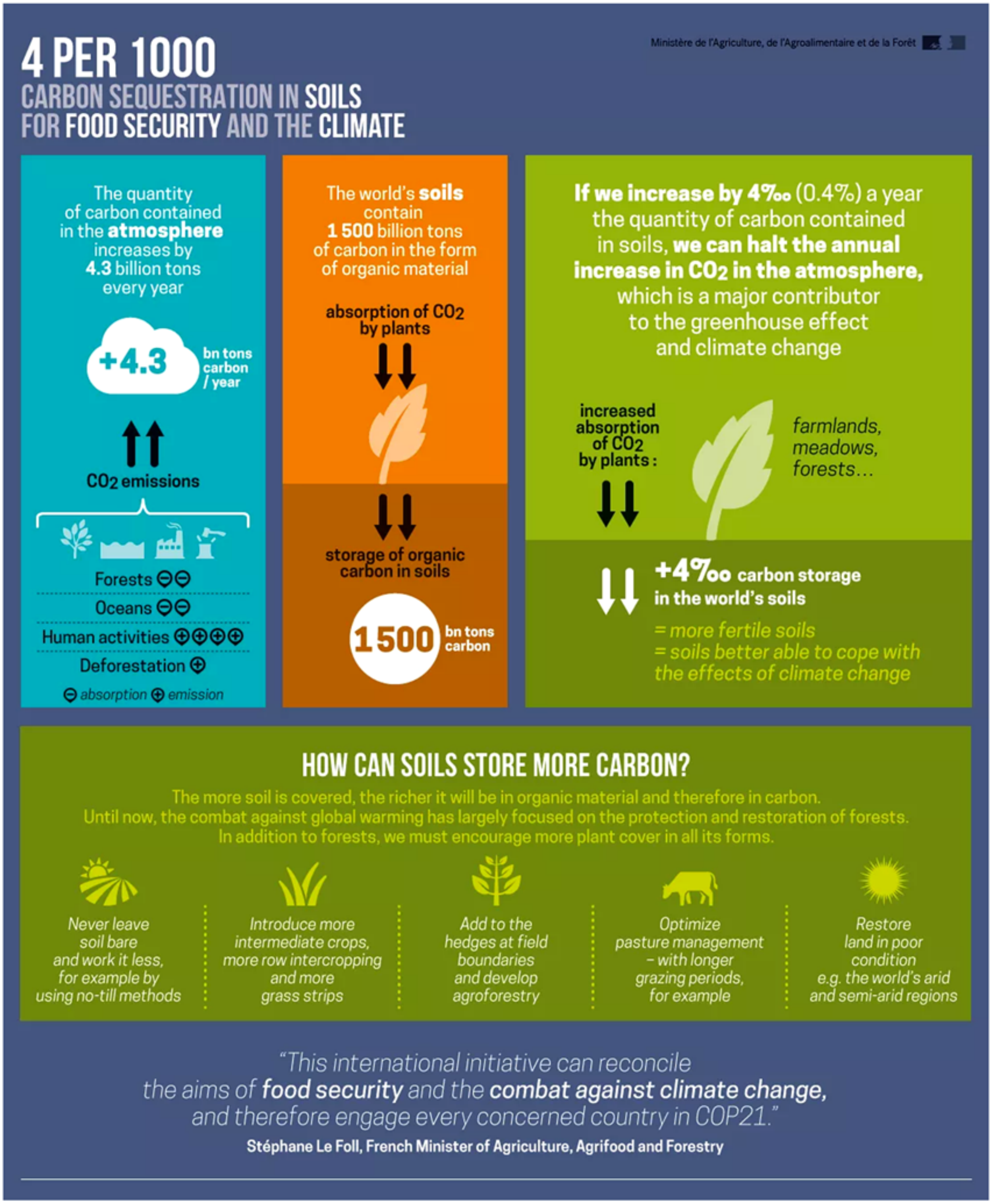


Figure 16.3
French Ministry of Agriculture, 4 per 1000 infographic.

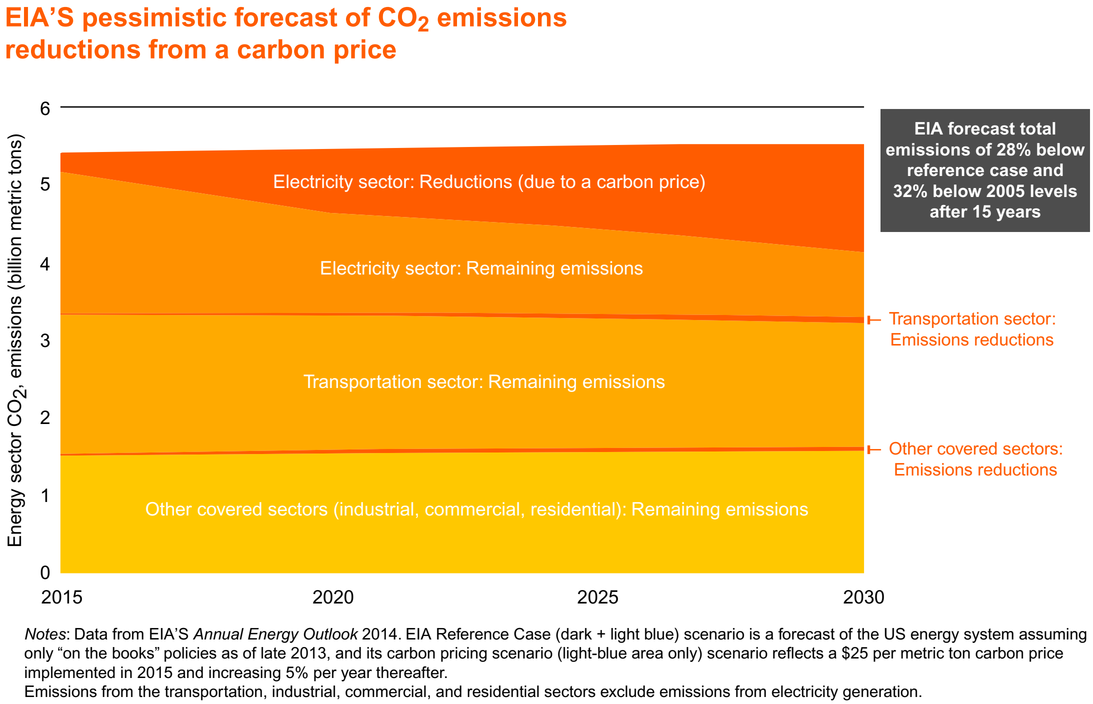


Figure 16.4
The US Environmental Protection Agency forecasts emissions reductions resulting from a carbon tax by industrial sector. Electric power sector shows sharp reduction in carbon emissions because fuel switching options are readily available. Heavy-duty transportation and high temperature manufacturing sectors have few options for fuel switching and their emissions remain constant.

16.6 Soil Carbon Monitoring and Verification

Soil science is complex, and carbon is not static. There are many methods for measuring carbon both in the soil and in the atmosphere. Some methods are direct and involve the use of instruments to directly count carbon in a sample, whereas others are based on statistical models. Satellites, drones, and remote sensing technologies are improving and have a role to play in providing data. Large-scale measurements of soil carbon that can be relied upon to be accurate for the purpose of financial transactions are feasible but would be labor-intensive to conduct.

An example of a comprehensive tool used to measure soil carbon on farms is the COMET-Farm tool developed by the USDA (US Department of Agriculture) and Colorado State University. COMET-Farm is a whole-farm carbon accounting system that guides users through a process of describing their farms and farming practices. The tool makes extensive use of satellite imagery, where users can define their parcels of land on the maps and then document the practices on that land in order to quantify their GHG emission resulting from both land-use practices and fossil fuel consumption. By documenting their land and farm practices, farmers can evaluate alternative methods that may allow them to improve their carbon balances.

16.7 A Blockchainized Soil Carbon Accounting Platform

Blockchain technology provides an effective accounting platform for the carbon-deposit system. Blockchains can be designed to be open or closed systems. Bitcoin cryptocurrency is the most well-known example of an open Blockchain system that allows anonymous participants. One major down side of open architecture is that it requires a complex and incredibly energy-intensive system of crypto-mining to ensure system security. A closed Blockchain system allows only authorized users to write to the Blockchain, avoiding the need for costly crypto-mining. Hyperledger is an open-source Blockchain platform intended for business designed to be a closed system. Hyperledger is run by the Linux Foundation with the contributions of major corporations such as IBM. The closed system can still be open for reading by the public, making auditing transparent, but only authorized participants are allowed to write to the ledger.

Blockchain applications work well in business processes where there are multiple participants from different organizations who need to be able to agree on transactions and trust the record-keeping. The carbon-deposit system could benefit from the full suite of Blockchain attributes and smart contracts. The participants on the network would include carbon emitters, carbon farmers, verification authorities for both emissions and sequestration, and system auditors. Smart contracts are protocols or rule sets embedded within the Blockchain that are largely self-executing and enforce a contract condition. Terms are specified within the contract and executed when specific conditions are met. Smart contracts ensure that transactions are carried out instantaneously and consistent with the terms of the predefined contract.

In practice, the carbon-deposit system would require that emissions be properly accounted for in the same manner that emissions would be assessed for a carbon tax. These records would be entered onto the Blockchain network and checked off by a certifier who would also be identified on the Blockchain. A single Blockchain would be dedicated to a single unit of carbon, i.e., 1 ton of carbon. Carbon farmers would have their efforts monitored. When a certification authority signs off on a ton of carbon being successfully sequestered, then that data would be entered into the Blockchain. Smart contract features in the Blockchain would enable participants to be automatically paid when conditions are met. Verification authorities would receive their fees and the carbon farmer would get paid. The Blockchains can be made viewable to the public so that third parties can audit the transactions to guard against fraud.

The challenge in the whole system, indeed, lies in accurately accounting for carbon on both the emissions and sequestration sides of the equation. Soil carbon content is in a constant state of flux and depending on processes occurring on any given parcel of land. Soil scientists will need to develop tools and statistical models that are accurate enough to be considered fair and reliable in the marketplace. These challenges are resolvable with modern technology, but the efforts will likely be time-consuming and require a lot of hands-on effort in the fields as well as the introduction of new technology.

16.8 Carbon-Deposit System—An Old Concept Run in a New Way

An illustrative historical example of intentional soil improvement can be found in the 1928 guidebook for the USDA's Arlington Experiment Farm located on the grounds of what is now Arlington Cemetery near Washington, DC. The Arlington Experiment Farm was located at the site from 1900 until World War II, when it was removed to make room for construction of the Pentagon. The farm thrived during those years though the land was originally in very bad shape. The guidebook describes the efforts taken to restore the soil to health.[13]

> The land was in poor condition for agriculture when the department acquired the farm in 1900. Not only had the cultivation of the land been neglected since 1861, but much of the top soil had been removed for lawn-making in the Arlington Cemetery. It was therefore necessary to devote much attention to the improvement of the soil in order to bring it into suitable condition for the purpose for which it was intended. This has been accomplished largely through the use of cover crops and stable manure. **Although it has been a tedious, expensive process, it has afforded an interesting demonstration in soil improvement**.

The successful efforts to restore the soil at the Arlington Experiment Farm took place over a century ago, but the practices described are the same as what is needed today; except today, it is needed across the entire Earth. Cover crops, manure, and the farmer's intention of rebuilding the soil are the same tools we use today, and the insights from Arlington that the process is tedious and expensive also still holds true. Among the challenges is that farmers do not typically get paid to practice soil restoration; they only receive income from crops they are able to harvest and bring to market. Farmers who practice soil restoration today only do so based on their own private calculations of improved yields and reduced inputs, and perhaps a personal moral calculation that soil restoration is better than soil depletion, but not because of any overt market rewards.

[13] United States Department of Agriculture. (1928). *Arlington experiment farm—A handbook of information for visitors*. Washington, D.C.: USDA.

The carbon-deposit system would provide the rewards for soil restoration and inject hundreds of billions of dollars into farms globally. This additional income could transform rural economics, particularly in the developing world where incomes are a fraction of those in America and Europe. The carbon-deposit system leverages human nature by putting money on the table that will drive people's behavior. If you pay farmers fairly to put carbon in the soil, they will do it. And the carbon-deposit system, by directly tying emissions to sequestration on a ton-for-ton basis, is logical, fair, and offers an incentivizing mechanism to achieve net-zero emissions. Ultimately, the embrace of carbon farming globally offers a turning point in humanity's battle with climate change.