Drawdown Solutions - Brief Descriptions

Abandoned Farmland Restoration There are an estimated 950 million to 1.1 billion acres of deserted farmland around the world—acreage once used for crops or pasture that has not been restored as forest or converted to development. To feed a growing population and protect forests from deforestation for fresh farmland, restoring abandoned cropland and pastureland is key. Bringing abandoned lands back into productive use can also turn them into carbon sinks.

Alternative Cement Cement is a vital source of strength in infrastructure. It is also a source of emissions, generating 5 to 6 percent annually. To produce common cement, limestone's calcium carbonate is split into calcium oxide (the desired component) and carbon dioxide (the waste). To reduce emissions from the limestone decarbonization process, the crucial strategy is to change the composition of cement.

Alternative Refrigerants Alternatives to fluorinated gases, such as ammonia or captured carbon dioxide, can replace these powerful greenhouse gases over time.

Bamboo Production Bamboo rapidly sequesters carbon in biomass and soil, taking it out of the air faster than almost any other plant, and can thrive on inhospitable degraded lands—the ideal place to put bamboo to work. Long-lived bamboo products can also store carbon over time.

Bicycle Infrastructure Bicycles offer an alternative to cars and fossil-fuel transport, especially in cities. Infrastructure is essential for supporting safe and abundant bicycle use, thereby curbing emissions.

Biochar Production Biochar is commonly made from waste material ranging from peanut shells to rice straw to wood scraps. During the slow baking of biomass in the near or total absence of oxygen, gas and oil separate from carbon-rich solids. The output is twofold: fuels that can be used for energy and biochar that can be used to enrich soil.

Biogas for Cooking Anaerobic digesters process backyard or farmyard organic waste into biogas and digestate fertilizer. Biogas stoves can reduce emissions when replacing biomass or kerosene for cooking.

Biomass Power Biomass feedstock can replace fossil fuels for generating heat and electricity. Biomass energy is a "bridge" solution—one that can help the world transition from fossil-fuel power to 100 percent clean, renewable energy. Carbon-rich biomass can be harvested to produce heat, create steam for electricity production, or be processed into oil or gas. Doing so trades in carbon that is already in circulation, cycling from atmosphere to plants and back again.

Bio Plastics Most plastics are made from fossil fuels, but bioplastics utilize plants as an alternative source of carbon. They often have lower emissions and sometimes biodegrade. Bioplastics can sequester carbon, especially when made from waste biomass.

Building Automation Systems A building automation system (BAS) uses data-informed calculations and computer systems, with skilled operators, to constantly scan and rebalance

energy use for greatest efficiency and effectiveness. These systems can control heating, cooling, lighting, and appliances in commercial buildings. They cut emissions by maximizing energy efficiency and minimizing waste.

Building Retrofitting Retrofitting brings energy efficiency to the existing built environment. Retrofits address electricity and fuel waste with better insulation and windows, efficient lighting, and advanced heating and cooling systems. Improved efficiency lowers existing buildings' emissions.

Car Pooling When people share common origins, destinations, or stops *en* route, they can ride together. Carpooling uses seats and fuel more efficiently, cutting emissions.

Coastal Wetland Protection Mangroves, salt marshes, and seagrasses sequester huge amounts of carbon in plants and soil. Protecting them inhibits degradation and safeguards their carbon sinks. Relative to their land area, they also sequester huge amounts of carbon in plants aboveground and in roots and soils below.

Coastal Wetland Restoration Agriculture, development, and natural disasters have degraded many coastal wetlands. Restoring mangrove forests, salt marshes, and seagrass beds to health revives carbon sequestration.

Composting Composting ranges in scale from backyard bins to industrial operations. The basic process is the same: ensuring sufficient moisture, air, and heat for soil microbes (bacteria, protozoa, and fungi) to feast on organic material. Rather than generating the greenhouse gas methane, the composting process converts organic material into stable soil carbon, while retaining water and nutrients of the original waste matter. The result is carbon sequestration as well as production of a valuable fertilizer.

Concentrated Solar Power Concentrated solar power (CSP), also known as solar thermal electricity, relies on the core technology of fossil-fuel generation: steam turbines. The difference is that rather than using coal or natural gas, CSP uses solar radiation as its primary fuel—free and clear of carbon.

Conservation Agriculture Conservation agriculture uses cover crops, crop rotation, and minimal tilling in the production of annual crops. It protects soil, avoids emissions, and sequesters carbon. Because conservation agriculture makes land more resilient to climate-related events such as long droughts and heavy downpours, it is doubly valuable in a warming world.

Distributed Energy Storage Distributed energy storage is the ability to retain small or large amounts of energy produced where you live or work and use it to meet your own needs. There are two basic sources of small-scale storage: stand-alone batteries and electric vehicles. If they are used to enable more reliance on renewables, there will be substantial climate benefits. Storage can ensure electricity is available, even when sunshine or breezes are not.

Distributed Solar Photovoltaics Rooftop solar panels are one example of distributed solar photovoltaic systems. Whether grid-connected or part of standalone systems, they offer hyper-local, clean electricity generation. In grid-connected areas, rooftop panels can put

electricity production in the hands of households. In rural parts of low-income countries, they can accelerate access to affordable, clean electricity—becoming a powerful tool for eliminating poverty.

District Heating In district heating and cooling (DHC) systems, a central plant channels hot and/or cool water via a network of underground pipes to many buildings. Heat exchangers and heat pumps separate buildings from the distribution network, so that heating and cooling are centralized while thermostats remain independent. DHC provides thermal energy collectively—and more efficiently.

Dynamic Glass Adaptive technologies, dubbed "smart glass," make windows responsive in real time to sunlight and weather, reducing a building's energy load for lighting and improving heating and cooling efficiency. Smart glass relies on *chromism*, the term for any process that causes material to change color.

Efficient Aviation Today, some 20,000 airplanes are in service around the world, producing at minimum 2.5 percent of annual emissions. Various technologies and operational practices can lower airplane emissions to some degree. They include better engines, wingtips, and light weighting to improve fuel efficiency.

Efficient Ocean Shipping More than 80 percent of global trade, by volume, floats its way from place to place. Shipping produces 3 percent of global greenhouse gas emissions. Fuel-saving ship design, onboard technologies, and operational practices can improve efficiency and trim emissions.

Efficient Trucks The impact of trucks on greenhouse gas emissions is oversized. Comprising just over 4 percent of vehicles in the United States and 9 percent of total mileage, they consume more than 25 percent of fuel—50 billion gallons of diesel each year. Worldwide, road freight is responsible for about 6 percent of all emissions, and growing. Fuel-efficiency is critical to reduce road-freight emissions. Existing fleets can be retrofitted, while new trucks can be built to be more efficient or fully electric.

Electric Bicycles Small battery-powered motors give electric bicycles a boost. It makes them a more compelling alternative to more polluting forms of motorized transport, namely cars. Electric bikes are the most environmentally sound means of motorized transport in the world today. They come in many shapes and forms and are accompanied by a small battery-powered motor that can make hills manageable, journeys swifter and longer trips more viable.

Electric Cars Electric motors supplant gasoline or diesel engines, which are polluting and less efficient. EVs always reduce car emissions—dramatically so when powered by renewable electricity. Compared to gasoline-powered vehicles, emissions drop by 50 percent if an EV's power comes off the conventional grid. If powered by solar energy, carbon dioxide emissions fall by 95 percent.

Electric Trains Trains transport 28 billion passengers and more than 12 billion tons of freight annually. Rail electrification enables trains to dispatch with dirty diesel-burning engines. When powered by renewables, electric trains can provide nearly emissions-free transport.

Farm Irrigation Efficiency Irrigation is essential for 40 percent of the world's food production. Because pumping and distributing water requires large quantities of energy, irrigation is a source of carbon emissions. Drip and sprinkler irrigation, among other practices and technologies, make farm water use more precise and efficient.

Forest Protection In their biomass and soil, forests are powerful carbon storehouses. The most critical of all forest types is primary forest, known as old-growth or virgin forest. With mature canopy trees and complex understories, these forests contain 300 billion tons of carbon and are the greatest repositories of biodiversity on the planet. Protection prevents emissions from deforestation, shields that carbon, and enables ongoing carbon sequestration.

Geothermal Power Underground reservoirs of steamy hot water are the fuel for geothermal power. It can be piped to the surface to drive turbines that produce electricity without pollution.

Grassland Protection Grassland Protection is the legal protection of natural, ungrazed grasslands from future grazing and/or conversion to annual cropland, perennial cropland, biomass or bioenergy crops. Protection leads to reduced land use change and the safeguarding of carbon sinks.

Green Roofs Green roofs use soil and vegetation as living insulation. Cool roofs reflect solar energy. Both reduce building energy use for heating and/or cooling.

Grid Flexibility The grid is the dynamic web of electricity production, transmission, storage, and consumption that 85 percent of the world relies on. Smarter, more flexible electric grids can cut energy losses during distribution. They are critical to enable renewables, which are more variable than conventional electricity generation.

Health and Education Two rights-based solutions have a large influence on global population: universal education and family planning. Increased access to and quality of voluntary reproductive healthcare, family planning resources, and 12-13 years of schooling are essential components to achieve the United Nations' 2015 medium global population projection of 9.7 billion people by 2050.

High Efficiency Heat Pumps Heat pumps extract heat from the air and transfer it—from indoors out for cooling or from outdoors in for heating. With high efficiency, they can dramatically lower building energy use.

High Performance Glass High-performance glass improves window insulation and makes building heating and cooling more efficient. By minimizing unnecessary energy use, it curtails emissions.

High Speed Rail High-speed rail offers an alternative to trips otherwise made by car or airplane. It requires special, designated tracks, but can dramatically curtail emissions. HSR is powered almost exclusively by electricity, not diesel.

Hybrid Cars A transitional technology, hybrid cars pair an electric motor and battery with an internal combustion engine. The combination improves fuel economy—more miles on a gallon—and lowers emissions.

Improved Clean Cookstoves Around the world, 3 billion people cook over open fires or on rudimentary stoves. Improved clean cookstoves can address the pollution from burning wood or biomass in traditional stoves.

Improved Rice Production Rice cultivation is responsible for at least 10 percent of agricultural greenhouse gas emissions and 9 to 19 percent of global methane emissions. That is because flooded rice paddies are ideal anaerobic environments for methane-producing microbes. Improved soil, nutrient management, water use, and tillage practices can improve rice production and reduce emissions.

Indigenous Peoples' Forest Tenure Indigenous communities have long been the frontline of resistance against deforestation; mineral, oil, and gas extraction; and the expansion of monocrop plantations. Secure land tenure protects indigenous peoples' rights. With sovereignty, traditional practices can continue—in turn protecting ecosystems and carbon sinks and preventing emissions from deforestation.

Insulation Insulation impedes unwanted airflow in or out of buildings. In new construction or retrofits, it makes heating and cooling more energy efficient, with lower emissions.

Landfill Methane Capture Landfill methane can be tapped, captured, and used as a fairly clean energy source for generating electricity or heat, rather than leaking into the air or being dispersed as waste. The climate benefit is twofold: prevent landfill emissions and displace coal, oil, or natural gas that might otherwise be used.

LED Lighting LEDs (light emitting diodes) use 90 percent less energy than incandescent bulbs for the same amount of light and half as much as compact fluorescents. By transferring most of their energy use into creating light—rather than heat, like older technologies—LEDs reduce electricity consumption and air-conditioning loads. Virtually any bulb currently in use can be replaced by LEDs.

Low Flow Fixtures Cleaning, transporting, and heating water requires energy. More efficient fixtures and appliances can reduce home water use significantly, thereby reducing emissions.

Managed Grazing Managed grazing involves carefully controlling livestock density and timing and intensity of grazing. Compared with conventional pasture practices, it can improve the health of grassland soils, sequestering carbon.

Methane Digesters Industrial-scale anaerobic digesters control decomposition of organic waste, and convert methane emissions into biogas, an alternative fuel, and digestate, a nutrient-rich fertilizer. At small scale, biogas can reduce demand for wood, charcoal, and dung as fuel sources. Digestate enriches home gardens and small agricultural plots.

Microwind Turbines Microwind turbines can generate clean electricity in diverse locations, from urban centers to rural areas without access to centralized grids. Today, they are often

used to pump water, charge batteries, and provide electrification in rural locations, all without producing greenhouse gases.

Microgrids A microgrid is a localized grouping of distributed electricity generation technologies, paired with energy storage or backup generation and tools to manage demand or "load."

Multistrata Agroforestry Multistrata agroforestry systems mimic natural forests in structure. Multiple layers of trees and crops achieve high rates of both carbon sequestration and food production. An acre of multistrata agroforestry can achieve rates of carbon sequestration comparable to those of afforestation and forest restoration, with the added benefit of producing food.

Net Zero Buildings A net zero building is one that has zero net energy consumption, producing as much energy as it uses in a year. Buildings with zero net energy consumption combine maximum efficiency and onsite renewables.

Nuclear Power Nuclear plants use fission to split atomic nuclei and release the energy that binds protons and neutrons together. It produces heat to boil water, which powers steam turbines that generate electricity. Nuclear power is slow, expensive, risky, and creates radioactive waste, but it has the potential to avoid emissions from fossil fuel electricity.

Nutrient Management Overuse of nitrogen fertilizers—a frequent phenomenon in agriculture—creates nitrous oxide. More efficient use can curb these emissions and reduce energy-intensive fertilizer production.

Ocean Power Wave- and tidal-power systems harness natural oceanic flows—among the most powerful and constant dynamics on earth—to generate electricity without pollution.

Offshore Wind Turbines Winds over sea are more consistent than those over land. Offshore wind turbines tap into that power to generate utility-scale electricity without emissions.

Onshore Wind Turbines Onshore wind turbines generate electricity at a utility scale, comparable to power plants. They replace fossil fuels with emissions-free electricity. Ongoing cost reduction will soon make wind energy the least expensive source of electricity, perhaps within a decade.

Peatland Protection and Rewetting Peatlands, also known as bogs or mires, are second only to oceans in the amount of carbon they store—*twice* that held by the world's forests, at an estimated 500 to 600 gigatons. Forestry, farming, and fuel-extraction are among the threats to carbon-rich peatlands. Protection and rewetting can reduce emissions from degradation, while supporting peatlands' role as carbon sinks.

Perennial Biomass Production Bioenergy relies on biomass—often annual crops such as corn. Perennial plants (e.g., switchgrass, silvergrass, willow, eucalyptus) are a more sustainable source and sequester modest amounts of soil carbon. Cultivated appropriately, they can

reduce emissions by 85 percent compared to corn ethanol. Replacing annuals with perennials also raises carbon sequestration in soil.

Perennial Staple Crops The dominant agricultural crops are annual—planted, harvested, and replanted every year. Perennials come back year after year, with similar yield and higher rates of carbon sequestration, and include important foods, such as bananas, avocado, and breadfruit. Compared to annual crops, they have similar yields but higher rates of carbon sequestration.

Plant-Rich Diets Consumption of meat and dairy, as well as overall calories, often exceeds nutritional recommendations. Paring down and favoring plant-based foods reduces demand, thereby reducing land clearing, fertilizer use, burping cattle, and greenhouse gas emissions.

Public Transit Streetcars, buses, and subways offer alternative, efficient modes of transport. Public transit can keep car use to a minimum and avert greenhouse gases. Urban transport is the single largest source of transportation-related emissions, and growing. With good urban design, mass transit can help embed mobility, livability, and sustainability in cities.

Recycled Paper Recycled paper can then be made into any number of products, from office paper to newsprint to toilet paper rolls. A particular piece of paper can be reprocessed roughly five to seven times, before fibers are no longer viable. It can be made into any number of products, from office paper to newsprint to toilet paper rolls. In addition to curbing emissions, recycled paper spares forests and reduces water use.

Recycling Recycling can reduce emissions because producing new products from recovered materials often saves energy. Forging recycled aluminum products, for example, uses 95 percent less energy than creating them from virgin materials.

Reduced Food Waste Roughly a third of the world's food is never eaten, which means land and resources used and greenhouse gases emitted in producing it are unnecessary. Interventions can reduce loss and waste, as food moves from farm to fork, thereby reducing overall demand.

Refrigerant Management Every refrigerator and air conditioner contains chemical refrigerants that absorb and release heat to enable chilling. HFCs, the primary refrigerants now used, have 1,000 to 9,000 times greater capacity to warm the atmosphere than carbon dioxide. Through an amendment to the Montreal Protocol, the world will phase out HFCs—starting with high-income countries in 2019, then some low-income countries in 2024 and others in 2028. Because 90 percent of refrigerant emissions happen at end of life, effective disposal of those currently in circulation is essential.

Regenerative Annual Cropping Building on conservation agriculture with additional practices, regenerative annual cropping can include compost application, green manure, and organic production. It reduces emissions, increases soil organic matter, and sequesters carbon.

Silvopasture Silvopasture is an ancient practice that integrates trees and pasture into a single system for raising livestock. Pastures strewn or crisscrossed with trees

sequester five to ten times as much carbon as those of the same size that are treeless, storing it in both biomass and soil.

Small Hydropower Placed within a free-flowing river or stream, small hydropower systems capture the energy of free-flowing water without using a dam and generate electricity without pollution.

Smart Thermostats Smart thermostats use algorithms and sensors to become more energy efficient over time, lowering emissions. Smart thermostats detect occupancy, learn inhabitants' preferences, and nudge users toward more efficient behavior. They can reduce consumption at times of peak energy use, peak prices, and peak emissions.

Solar Hot Water Solar water heating—exposing water to the sun to warm it—can reduce that fuel consumption by 50 to 70 percent. SWH is among the most effective ways to convert solar energy into thermal energy.

Sustainable Intensification for Smallholders There is a gender gap in agriculture in low-income countries. Women have less access to a range of resources, from land rights and credit to education and technology. If all women smallholders receive equal access to productive resources, sustainable intensification practices can increase smallholder yields, which, in theory, will reduce demand to clear additional land.

System of Rice Intensification The System of Rice Intensification (SRI), developed on Madagascar in the 1980s, is a holistic approach for sustainable rice cultivation. By minimizing water use and alternating wet and dry conditions, it minimizes methane production and emissions.

Telepresence By integrating a set of high-performance visual, audio, and network technologies and services, people who are geographically separated can interact in a way that captures many of the best aspects of an in-person experience. It cuts down on travel—especially flying—and its emissions.

Temperate Forest Restoration The world's 1.9 billion acres of temperate forests are a net-carbon sink According to the World Resources Institute, more than 1.4 billion additional acres are candidates for restoration—either large-scale, closed forest or mixed mosaics of forests, more sparsely growing trees, and land uses such as agriculture. With restoration comes additional carbon sequestration.

Tree Intercropping Tree intercropping—intermingling trees and crops—increases the carbon content of the soil and productivity of the land. The arrangement of trees and crops varies with topography, culture, climate, and crop value.

Tree Plantations (on Degraded Land) Creating new forests where there were none before is the aim of afforestation. Degraded pasture and agricultural lands, or other lands corrupted from uses such as mining, are ripe for strategic planting of trees and perennial biomass.

Tropical Forest Restoration Tropical forest restoration is growing and may sequester as much as six gigatons of carbon dioxide per year. As a forest ecosystem recovers, trees, soil, leaf litter, and other vegetation absorb and hold carbon.

Utility-Scale Energy Storage Large-scale energy storage ensures electricity supply can match demand. Energy storage—daily, multi day, and longer-term or seasonal—is vital to reduce "peaker" emissions from energy plants that are started and stopped to meet peak demand. Large-scale energy storage also can accommodate the shift to variable renewables, namely wind and solar.

Utility-Scale Solar Photovoltaics Solar photovoltaics can be used at utility-scale—with hundreds or thousands of panels—to tap the sun's clean, free fuel and replace fossil-fuel electricity generation.

Walkable Cities Walkable cities use planning, design, and density to maximize walking and minimize driving, especially for commuting. They have *walk appeal*, thanks to a density of fellow walkers, a mix of land and real estate uses, and key infrastructure and design elements that create compelling environments for people on foot.

Waste-To-Energy Waste-to-energy processes (incineration, gasification, and pyrolysis) combust waste and convert it to heat and/or electricity. Emissions reductions come with health and environmental risks, however. It can help move us away from fossil fuels in the near-term, but is not part of a clean energy future.

Water Distribution Efficiency Pumping water requires enormous amounts of electricity. Addressing leaks in water-distribution networks, especially in cities, can curb water loss, energy use, and emissions.