Refrigerant Management

Refrigerant chemicals (primarily HFCs) have a global warming potential 1,000-9,000 times greater than CO2. In October 2016, 170 countries signed an amendment to the Montreal Protocol agreement to phase out HFCs beginning in 2019. In the mean time we need to manage existing HFCs already in use primarily through leak prevention and recovery/reuse at the end of life of HFC using equipment.

Net Cost: N/A

Onshore Wind

Wind energy promises to be the cheapest and cleanest form of energy (once subsidies are equalized). The wind energy potential of just three states — Kansas, North Dakota and Texas — would be sufficient to meet the electricity demand of the whole US. While its reliability is plagued by intermittent weather conditions, this problem could be largely overcome with a national grid that would distribute the energy where needed.

Net Cost: $1.23 trillion (to go from 2.9% to 21.6%)

Offshore Wind

Wind energy promises to be the cheapest and cleanest form of energy (once subsidies are equalized). While its reliability is plagued by intermittent weather conditions, this problem could be largely overcome with a national grid that would distribute the energy where needed. Offshore wind is more expensive than onshore for obvious reasons, but benefits from not requiring the purchase or lease of land

Net Cost: $572.4 billion (to go from .1% to 4%)

Geothermal

Geothermal taps the subterranean “earth heat” and uses it to heat water to tap the heat and/or generate electricity. Geothermal “hot spots” are found on less than 10% of the planet, but new technologies (E.g. Enhanced Geothermal Systems) increase its accessibility. Geothermal is not without its negative environmental impacts such as some CO2 emissions along with other gasses. While drilling is expensive the heat is free.

Net Cost: -$155.5 billion (to go from .66% to 4.9%)

Solar Farms

Solar farms provide utility scale energy generation without emitting CO2, mercury, particulates and nitrous and sulfur oxides. Solar farms are cheaper to install than roof top solar and have a higher conversion capacity, though this form of generation requires transmission to end users.

Net Cost: -$80.6 billion (to go from .4% to 10%)

Rooftop Solar

While less efficient than solar farm generation, rooftop solar installations have the benefit of localizing the production where it is used. A distributed energy grid is also less “brittle” and subject to take down. Roof top solar also eliminates the need and cost for large scale generation and distribution which lowers the cost/watt of large generation.

Net Cost: $453.1 billion (to go from .4% to 7%)

Nuclear Energy

Nuclear is on the list because it does not emit CO2 in generation, but it has other problems of its own. Still many believe it will continue to be an important part of carbon reduction strategy for the next 30 years because nuclear plants are better alternatives to the still growing number of coal fired plants. It is, however, the only generation method that is getting more expensive over time.

Net Cost: $.88 billion (to go from 11% to 12%)

Plant Rich Diets

The target for this strategy is to convince 50% of the people to reduce their intake of meat. The amount of protein in a typical American’s diet goes well beyond dietary requirements – as much as 36% higher. While no cost has been projected because of the huge variability, various implementation approaches would have associated costs – for example ad campaigns to change dietary behaviors, subsidies to ranchers to not raise beef, health insurance incentives for vegetarian customers, etc.

Net Cost: Varies

Reduced Food Waste

The target for this strategy is a 50% reduction in food waste. Currently 1/3 of the food grown or produced in the world does make it to the fork contributing 8% of the world's ghg emissions. There are also social implications given that 800 million people world-wide go hungry. The costs associated with this strategy will vary with implementation approaches. Effectively achieving this goal country wide would require a national collection and composting infrastructure.

Net Cost: Varies

Conservation Agriculture

Conservation agriculture adheres to three core principles: minimize soil disturbance (no till), maintain soil cover (usually with nitrogen fixing cover crops) and crop rotation. Conservation agriculture still allows for fertilizers and pesticides. This method allows the micro-system of the soil to maintain its life and health.

Net Cost: $37.5 billion (to go from 177 million acres to 1 billion)

Silvopasture

Silvopasture is the practice of integrating trees and pasture for raising livestock. Cattle and other ruminants require 30-40% of the world's arable land and produce roughly 20% or the ghg's. Trees on pastures not only sequester carbon 5-10 times faster than open range and result in higher livestock yields. In addition, the trees themselves may yield additional products while protecting livestock from weather and reducing the need for soil additives, holding water and preventing soil erosion.

Net Cost: $41.6 billion (to go from 351 million acres to 554 million)

Tropical Staple Trees

Annual crops (like food trees and legumes) sequester more carbon that perennial crops. Currently 2/3 of cultivated land is devoted to annuals. While less conducive to mechanical harvesting, they require less work in cultivation, can grow on sloped land and contribute to soil and water conservation.

Net Cost: $120.1 billion (to go from 116 million acres to 269 million)

Regenerative Agriculture

Regenerative agriculture restores degraded land and sequesters carbon. The approach includes no till, diverse cover crops, no fertilizers, multiple crop rotation so that soil and land productivity is continually improved.

Net Cost: $57.2 billion (to go from 108 million acres to 1 billion)

Managed Grazing

Managed grazing imitates what wild migratory herds do. Herbivores can actually enrich land by distributing soil with their hooves and fertilizing with their manure – IF there is proper ratio of grazing to 'pasture rest.' Best results occur when grazing is rapid and intense and rest periods are long. Properly rotating livestock can not only enrich pasture land, but sequester carbon and a faster rate.

Net Cost: $50.5 billion (to go from 195 million acres to 1.1 billion)

Tree Intercropping

Tree intercropping is growing crops in between trees. Intercropping not only helps replenish nutrients in the soil, but the trees provide wind breaks for the crops and a reduction in soil erosion.

Net Cost: $147 billion (adding 571 million acres)

Family Planning

Increased adoption of healthcare and family planning is essential to both the SDG's and to carbon emissions reduction because of the impact on global population numbers. The goal is no unwanted births. Currently there are 74 million unintended pregnancies every year. In the US it is estimated that 45% of pregnancies are unintended.

Net Cost: N/A

Clean Cookstoves

The cooking fuels used by 40% of humanity include wood charcoal, animal dung, crop residues and coal. Their smoke contributes to 4.3 million premature deaths each year. Globally household air pollution is second only to unsafe drinking water in causing environmental death and disability and contribute to 2-5% of global ghg emissions.

Net Cost: $72.2 billion (to go from 1.3% of addressable market to 16%)

Afforestation

This strategy involves creating new forests (preferably with native trees) where there have been none for over 50 years. This would include degraded pasture and agricultural land, land corrupted by mining or compromised by erosion, abandoned lots, highway medians and waste lands. If not displacing existing forest, timber plantations fit within this strategy.

Net Cost: $29.4 billion (to go from 195 million acres to 1.1 billion)

Improved Rice Cultivation

Currently rice production is responsible for 10% of global ghg emissions because of their high methane output. A new approach to rice growing – called the System of Rice Intensification – increases yield by 50-100% while reducing water consumption by 25-50% and seed use by 80-90% while increase the crops resistance to drought, flooding, and storms.

Net Cost: None (to go from 8.4 million acres to 133 million)

Farmland Restoration

Changing climate, destructive farming practices, drained ground water and urban migration have left over a billion acres of once productive farmland abandoned. Restoring these lands not only contributes to food production, but improves the carbon sequestration power of the land. Some of this land will naturally restore, but take a long time. Other land needs purposeful attention.

Net Cost: $72.2 billion (restoring 424 million acres of the currently abandoned 1 billion acres)

Temperate Forests

Temperate rainforests are not as threatened as tropical forests and have, in fact, been increasing in the last decades. From the 1990's to 2000's the carbon sink provided by US forestland rose 33%. However, climate change threatens our forested land. This strategy speaks mostly to managing and maintaining to prevent loss.

Net Cost: too variable to determine (to go from 1.9 billion acres to 2.1 billion)

Tropical Forests

This strategy seeks to restore 435 million acres of forest land. Forests once covered 12% of the planet. Now it is just 5%. When forests are cut or burned, they discharge their stored carbon all at once. Left to grow they sequester carbon year on year. Forest also provide other vital eco-system services such as water and soil conservation, habitat, and weather breaks.

Net Cost: too variable to determine

Peatlands

Peat is a thick, mucky, waterlogged substance made up of dead and composting organic matter. Peat bogs are second only to the ocean in their carbon sequestration power; they have ten times more carbon holding capacity per acre than other ecosystems. This strategy involves protecting and restoring peatlands.

Net Cost: too variable to determine (to go from 7.9 million acres to 608 million)

Educating Girls

In companion with access to family planning, educating girls has a strong influence on family size and global population. The target here is to assure every girl access to 13 years of schooling.

Net Cost: N/A

Insulation

According to the US Green Building Council, air filtration accounts for 25-60% of energy used to heat and cool a home. Insulation is one of the most practical and cost-effective ways to make buildings more energy efficient.

Net Cost: $3.66 trillion (to insulate 54% of existing commercial and residential buildings)

Concentrated Solar

Instead of capturing sunlight and turning it directly into electricity, concentrated solar uses mirrors to focus radiation from the sun to heat fluid, produce steam and turn turbines. While not as cost effective per kilowatt hour as PV panels and still a centralized method of energy generation requiring transmission, it has the advantage of energy storage since heat can be cheaply and effectively stored in the hours there is no sun light. California has had a concentrated solar plant running since the 1980's.

Net Cost: $1.32 trillion (to go from .04% of generation to 4.3%)

Electric Vehicles

Currently EV's make up a tiny portion of total vehicle sales. But that could change quickly. Adoption of the technology is hampered mostly by today's limited driving range and a dearth of charging stations. Also while an improvement over CO2 producing internal combustion engines, the impact of EV's will be bigger still when the electricity they consume is generated by renewable power. The estimates for this strategy assume current generation mix.

Net Cost: $14.15 trillion (to get to 16% of total passenger miles)

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 the heating and cooling media are centralized while thermostats remain independent. This system is more efficient in densely developed cities than having separate small units in each building.

Net Cost: $457.1 billion (to go from .01% of heating demand to 10%)

Multi-strata Agroforestry

Multi-strata agroforestry follows nature's design blending an overstory of taller trees and an understory of one or more layers of crops maximizing both vertical and horizontal space. This design sequesters carbon at the rate of a forest while producing food at the same time. This approach is also well suited to steep slopes or degraded farmland. While quite profitable once established, the costs can be high for initial installation.

Net Cost: $26.8 billion (to go from 247 million acres to 293 million acres)

Wave and Tidal

Wave and tidal energy systems harness the natural oceanic flows to generate electricity through a variety of methods. This is an appealing energy choice because it is constant and reliable. It requires no energy storage and creates no visual blight. Maintenance is an issue because of the unpredictable natural conditions, and erosion from salt water. There is also potential risk to sea life and disruption of marine traffic.

Net Cost: $411.8 billion (to go from .0004% of energy generation to .28%)

Methane Digestors

Agricultural, industrial and human digestion processes create an ongoing stream of organic waste. Unmanaged this waste generates tons of methane which has a particularly high global warming potential. Anaerobic digestors can capture this gas and prevent it from being released. Additionally, it can use the gas to generate electricity or used directly as fuel for vehicles or cook stoves. The solids remaining from this process provide nutrient rich soil amendments.

Net Cost: $201.4 billion (to grow to 69.8 gigawatts of installed capacity)

Ships

More than 80% of global trade is conducted by shipping. Ships are the most carbon efficient means of transporting goods but the huge volume still makes a significant carbon impact. There ae a myriad of strategies and retrofits than can ameliorate their impact – e.g. sleeker hull design, plugging in at dock instead of running ships generators, lower sailing speeds to save fuel.

Net Cost: 915.9 billion (for a 50% efficiency gain)

Biomass

While full of its own problems, biomass as an energy source would provide "on demand" energy generation to supplement intermittent renewables. This only works if it is derived from non-food farm waste or appropriate energy crops like switch grass, or shrub willow. This energy source does release carbon when burned, but it is carbon that would otherwise enter the atmosphere during decomposition.

Net Cost: $402.3 billion (assumes all biomass is derived from non-food feedstock)

Bamboo

Bamboo sequesters carbon faster than almost any other plant and can thrive on inhospitable degraded lands.
It is also a plant that doesn't need encouraging. It reaches its full height in one season growing at the rate of 1 inch/hour. Once cut, it resprouts again and again. It is also valuable as a harvested material replacing much higher impact products like timber, cotton, steel and plastic.

Net Cost: $23.8 billion (to go from 77 million acres to 114 million on degraded or abandoned land)

Mass Transit

This strategy seeks to increase us of mass transit to 40% of urban travel. The transportation sector is responsible for 23% of global emissions. Because mass transit is spatially leaner, it leaves more land for other uses. It also makes a city more equitable by serving all. It has a high initial cost and also faces barrier related to public perception or lack of appropriate city planning.

Net Cost: Data too variable to be determined

Trucks

Trucks convey 70% of domestic freight tonnage. Building or retrofitting trucks with better engines, lighter weights, less rolling resistance, hybridization and automatic engine shutdown. Additional carbon saving measures have to do with efficient routing, avoiding empty loads and driver training.

Net Cost: $543.5 billion (to go from 2% of trucks with fuel saving technologies to 80%)

Alternative Cement

Making cement requires roasting limestone and aluminosilicates at very high temperatures. Making one tone of cement is equal to burning four hundred pounds of coal. Alternative cement involves replacing part of the cement ingredients with materials that don't need or have already been through a heating process – for example blast furnace slag and fly ash which is a residual of coal-burning plants.

Net Cost: -$273.9 billion (assuming 9% of cement is made with from a blend of conventional cement and 45% fly ash)

Forest Protection

The target is to go from 1.6 billion acres of old growth forest land to 2.3 billion. These lands are important not just for their sequestration but because of the eco-system services they provide: habitat, soil protection, flood control, wild food production and a store of biodiversity.

Net Cost: Too varied to predict

Indigenous Peoples' Land Management

By protecting the land tenure of indigenous peoples and by increasing the land under their stewardship from 1.3 billion acres to 2.2 billion we would not only protect an important sequestration resource but honor the ancient claims and human rights of indigenous populations and help protect the people most vulnerable to climate change.

Net Cost: Too variable to determine

LED Lighting - Households

Light emitting diodes (LEDs) use a process called electroluminescence that create charged electrons that emit photons – or units of light. LEDs use 90% less energy and produce almost no waste heat. They also last much longer than other types of bulbs. Conversion to LEDs is already under way and expected to speed once the price drops to a competitive point.

Net Cost: $323.5billion (to cover 90% of household lighting and 80% of commercial)