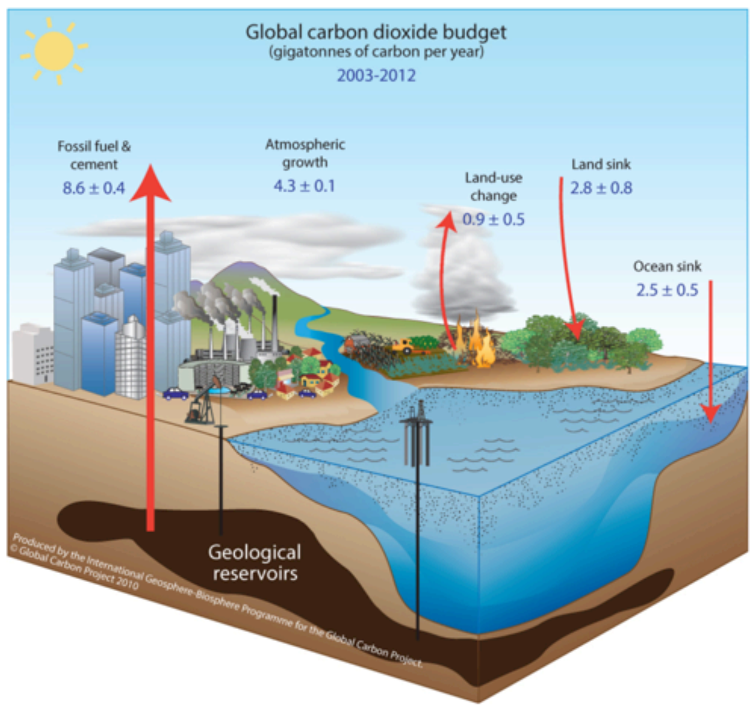
WFI'S CARBON NARRATIVE

Summary: Waterfield Farms is committed to growing affordable, sustainable, delicious, nutritious and healthy food, and part of this commitment is a focus on addressing climate change. WFI is in a unique position to create a transformative carbon-negative source of food, and is working to initiate a food-based market that could slow, or even reverse, climate change. This document briefly discusses the key issues of climate change, how grasslands and pasturelands sequester carbon at scale, dilemmas in the productivity of grasslands and pasturelands, and discusses several ways of solving this dilemma. Also discussed is how WFI's process can sequester more carbon than it emits in the food it grows and how WFI's model can be applied to other farms at scale beyond what most pasture raised meats or organic farms can accomplish. WFI believes that the focus on agriculture, and grasses in particular are the only mechanism known today, to not just bring the planet to net-zero carbon emissions, but sequester already emitted carbon, and bring atmospheric CO2 levels back to pre industrial levels in around fifty years time.

CLIMATE CHANGE

Most climate experts (97%) say that a 2-degree rise in the average global temperature is enough to cause dramatic changes in our ability to grow food, cause coastal flooding from sea level changes, force human migration and many other challenges. The world has already had nearly a 1-degree rise in temperatures since the beginning of the industrial age, when large amounts of fossil fuels started to be burned and is already experiencing many of the impacts of this rise in global temperatures.



Humans are currently putting a *net* amount of 4.3 billion tons of Carbon into the atmosphere that is a main factor causing this temperature rise. (Humans are emitting 8.6 BTs, but minus the globes natural ability to absorb carbon the net emissions are 4.3BTs.)

As a result of this added carbon, atmospheric CO2 has risen from pre-industrial levels of 280 PPM, to well past the 350 PPM maximum, a level that is estimated to keep global temperatures from climbing above a two-degree level of crop killing and city flooding levels.

In 2016, the world exceeded 400 PPM, and we are on a trajectory to hit 700+ if nothing is done to lower carbon emissions. Due to a lag between CO2 increases and temperature increases and other climate impacts, exceeding 350 PPM slightly and then declining will leave us a very challenged and tumultuous but probably livable world, similar to what we all see now. Remaining at 400 to 500 PPM or higher creates an untenable problem.

SOIL LOSS:

Concurrent with and related to climate change is the issue of our rapidly vanishing topsoil's. The US has lost ~87% of its topsoil since the early 1800's. This is due to the tilling of soil and exposing it to erosion and oxidation. There used to be an average soil depth of over 8 feet across the US, and now there is ~9 inches. On average the US has only 60 to 100 years of soil left. There is the same trend globally. On average the world loses an area of cropland the size of the state of Indiana every year due to soil loss. Several studies calculate that as much as 30% of the excess carbon in the atmosphere has come from lost topsoil. This indicates that the bulk of our lost soil (soil carbon) has moved from our land into our atmosphere as CO_2 and then into our oceans. So not only is lost topsoil a crisis for food production, it is also a large contributor to climate change.

FRESH WATER

Independent of but related to and exasperated by soil loss and climate change is a growing shortage of fresh water. Fresh water resources are currently overtaxed and most reserves have been shrinking unrelated to climate change. One example in the US is the Ogallala Aquifer, which yields about 30% of the ground water used for irrigation in the United States. Some estimates indicate this aquifer could be depleted in the next 10 to 15 years. Shifting climate patterns attributed to climate change and loss of soil carbon is hurting the ability of soil to store water for use in dry years. By 2025, the World Bank predicts that 66% of the world will run short of fresh drinking water and 80% of the world will be fresh water limited by 2050. The water shortages for agriculture will be immense. Meeting crop demands in the next ten years, for 2025, when the world's population will be 'just' 8 billion, will require a new volume of water equivalent to the entire flow of the Nile river, *times ten*!

POPULATION:

Compounding all of the above, the world's population is set to grow from ~7 Billion currently to over 10.5 Billion by 2050. The consequence of either of topsoil loss, water shortages and crop failure from excess heat caused by or made worse by climate change will most certainly not allow the human population to grow gracefully. The resulting strain on society is likely to be immense. Resolving these issues will probably be some of the largest challenges ever faced by humans.

SOLUTIONS:

There are many technologies and strategies, including renewable energy, energy efficiency, and organic farming practices that hold promise in slowing and eventually stopping human CO_2 emissions. If rapid action is taken, atmospheric CO_2 may peak in 20 to 30 years at 430 to 460 PPM. These levels would be disruptive to social, environmental and economic systems, but would be manageable if brought down quickly. However, none of these technologies take CO_2 back out of the air. Without new solutions, already emitted CO_2 remains like a giant blanket around the globe warming the planet and cooking civilization. Some portion of atmospheric carbon, 25% to 30%, will be absorbed into the ocean but the rest will remain at dangerous levels for thousands of years.

SEQUESTRATION:

The world needs a system that not only stops putting carbon in the air, like wind and solar, but one that actually pulls excess CO_2 out of the air and stores it (sequesters it) in some stable form, on a massive scale. Wind, Solar and all other forms of sustainable energy are at best carbon-neutral, but none are carbon-negative. <u>None have the ability to remove CO_2 from the air</u>.

PHOTOSYNTHESIS:

To date, the only know systems that can sequester CO_2, at a large and affordable scale, are plants that convert inorganic CO_2 from the air into organic carbon via photosynthesis. Plants, like trees and grasses can 'pump' CO_2 from the air and store it in the ground as carbon sequestered in plant biomass and soil. This process also builds /grows topsoil, which improves water storage capacity of the soil, and can help recharge depleted groundwater. Since there is such a large deficit of topsoil, this represents a large empty reservoir to store carbon back into the ground. As much as one third, or 33% of all excess CO_2 has come from soil, this represents a large 'hole in the ground' where sequestered carbon could be stored, if that soil were to be regrown.

Growing trees works well at sequestering carbon but the bulk of the stored carbon in a tree is above ground leaving it vulnerable to burning, blowing over and rotting and other forms of instability. Many have proposed planting more trees, but so much forest has been converted into croplands, planting back trees may cause a large loss in farmland and food production capacity. While WFI is clearly in support of reforestation efforts, it seem much more practical to convert the kind of crops that are grown on farmland to those that sequester carbon more efficiently than converting fields back to forests.

Grasses are more efficient at sequestering CO_2, and store their carbon in a more stable form in soil. Just one percent of grass' carbon is above ground as grass, the remaining 99% is stored in a stable form below ground as roots and soil. It remains stable unless it is turned over for farming.

Currently 60% to 70% of all US farmland is used to produce grains for animal feed. Globally 33% of all farmland is used to grow grains for animal feed. If conventional crops like corn that are grown to feed livestock were converted to grow grasses to feed animals, then a large potential exists to utilize grasses ability to sequester carbon. A widespread global conversion of cropland to grasslands could sequester billions of tons of atmospheric carbon back into our soil, re-growing depleted soil, reduce water stress in agriculture and help stem the worst ravages of climate change. Over time this could return levels of atmospheric carbon to pre-industrial norms.

A THOUGHT EXPERIMENT:

Assume for the moment that the world's economy could become carbon neutral in 25 years. With a declining rate of emissions toward zero, CO_2 would still rise from today's level of 401 to around 458 PPM, but would then remain around 458 PPM unless something were to pull all of that CO_2 out of the atmosphere.

Various studies and trials have shown that grass fields/ pasturelands can sequester carbon at a rate of 1.022 to 1.70 tons of Carbon per acre per year. Soils can absorb carbon at this rate for a period of 20 to 30 years before they become saturated, however they may be able to store longer depending on various growing techniques.

Using the lower sequestration rate from above of 1.022 Tons of carbon per acre per year, and a conversion rate of 33% of crops to grasslands it would take 56 years of grasses absorbing carbon from the air and storing it as soil carbon (new soil) to lower atmospheric CO_2 from 458 PPM to the maximum tolerable limit of 350 PPM. It would take 92 years to lower to the more sustainable pre-industrial levels of 280 PPM. Using the highest known sequestration rate of 1.7 tons, it would take 34 years to drop CO_2 to 350 PPM, and 55 years to drop to 280 PPM. The chart on the next page shows CO_2, temperature and soil levels rising and falling based on these scenarios.

It is generally considered necessary to get CO_2 levels down to or below 350 within 50 years to avoid the worst ravages of climate change. The faster, and the lower it drops the less the negative impact will be. So, it can be seen using either the average or maximum known sequestration rates that grass production could roughly accomplish this goal.

The above analysis assumes the world is not emitting any net new carbon, is 'carbon-neutral' for electricity, transportation etc., within 25 years. Currently the world is emitting 4.3 billion net tons of Carbon per year. While the rate of emissions has been increasing, over the last three year's growth has slowed to 0.7% from 2.3% annual increases. Emissions are finally dropping for some developed nations as well as efforts to slow growth in developing economies. While this is good progress, it is unlikely the planet can become carbon neutral in 25 years without a dramatic change in global politics.

Assuming emissions stay flat at 4.3 billion, (and don't start rising again) and using the sequestration rate of 1.7 and 33% grass base, grasslands would sequester 6.88 Billion tons /year, offsetting current emissions of 4.3 and still sequestering 2.58 billion tons /year, making the world carbon negative even with current fossil fuel emissions not declining. To remove excess CO_2 down to pre-industrial levels at this rate it would take 89 years to reach 350 PPM or 147 years to reach 280 PPM. Leaving CO_2 at these levels for this long would likely leave us a climate, geography and world order so changed it would be unrecognizable to us today. This is a far less viable path for society as we know it.

The possibility exists, that with some research, sequestration rates could be pushed from 1.7 to 2 tons per acre per year for grass production. If this were done it would take 60 and 100 years to drop CO_2 to 350 and 280 respectively with the globe still emitting 4.3 billion tons per year. This is still not fast enough to prevent dramatic warming. The rate would have to be pushed to 3 tons per acre, per year to get CO_2 down to the 280 levels in less than 50 years. There are a few studies that show sequestration rates at these levels but it is unlikely they could be sustained consistently every year, and implemented widely across the US let alone world wide.

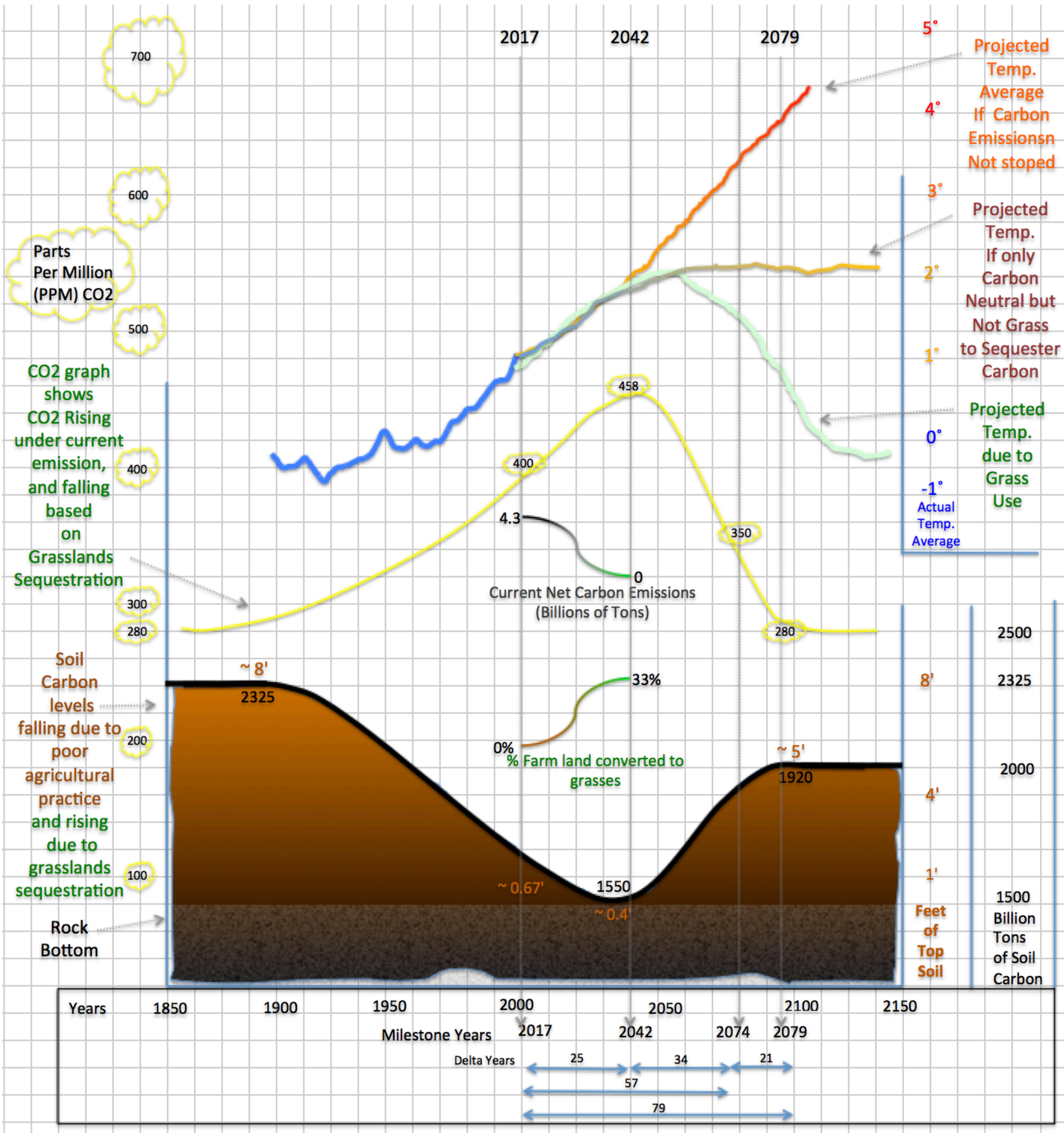
There are other options to increasing the sequestration rate like converting more land than the noted 33% level, reducing conventional farming carbon emissions by using more organic production techniques, conservation-tillage, or the use of or improvements in existing and holistic pasturelands management. If conventional grain production were converted to using conservation tillage or grain drilling on top of grasslands and as part of a crop rotation process, the possibility exists to convert almost all grain production away from conventional tillage. This would keep soils covered, while still producing conventional grains for human not animal consumption. The carbon impact of this hybrid production needs to be molded and tested, but a rough guess is it would have 1/8 to 1/4 of the carbon sequestration rate of conventional grasslands. Glomalin, a glycoprotein of several mycorrhizal fungi that live on plant roots is key in how soils store carbon. Research into Glomalin stimulation, could further improve carbon sequestration rates, along with the incorporation of biochar and other soil amendments.

Some studies show that if all of this is done concurrently, land area and sequestration rates could be large enough to get CO_2 down to 280 PPM in less than 50 years with emissions remaining at current levels. WFI's perspective is this is unlikely without strong market incentives, as passions for conservation or regulations alone will not work, as discussed below. Any approach needs to be viable in a market that incentivizes farmers to adopt the practices as ways to either lower costs or improve crop yields and profitability.

While grasslands conversion is a powerful tool, it likely cannot stop climate change on its own especially considering the consequences of Ocean CO_2 pollution, which will continue as long as excess human CO_2 emissions continue. There still needs to be a large push to bring CO_2 levels down close to a net-zero level.

The below chart shows the impact of declining soil tilth and rising CO_2 levels, followed by the possibility of rebuilding soil tilth and reducing CO_2 levels using grasslands, concurrent with lowering human carbon emissions to near zero. Average global temperatures are modeled showing, no action (ever rising temperatures), only stopping new CO_2 emissions, but not sequestering emitted carbon, (dangerously high but not rising temperatures), or lowering and sequestering atmospheric CO_2 via grasslands conversion into new soils, (temperatures falling to historically normal, pre-industrial levels).

Chart showing the correlation between dropping and rising soil levels, CO2 and Temperature:



As show in hundreds of studies the relationship between increasing CO2 and temperature rise is very closely correlated. Unlike other charts, the scale on this chart for the temperature graphs has been lifted above the CO2 curve for clarity so they are not overlapping lines. The relationship between Temperature, CO2, Soil-Carbon and Soil-Depth can be seen better this way.

The two small Curves in the center of the chart showing dropping carbon emissions and conversion of farmland from tilled crops to grass crops, have no scale, and are merely representative, of an assumed time line.

Please see the attached spreadsheet that shows the data and calculations used to create this chart.

The key point this chart shows is that by sequestering CO2 into grasses, topsoil could be rebuilt by as much as five feet, lowering atmospheric CO2, and in time bringing temperatures back to historical levels observed before the advent of the industrial era.

A LARGE CAVEAT:

The data for this graph and analysis has been assembled from different sources, many of which do not precisely agree. It is based on certain somewhat simplistic assumptions about carbon sequestration from the air and does account for a host of feedback loops, like CO2 coming back out of the oceans, methane emissions, and *many others. On the whole, this at best only shows the general possibility and relationships noted to paint a 'big picture' view of the value of rebuilding topsoil and lowering atmospheric carbon through soil carbon sequestration. The actual rates and years noted could vary considerably. In spite of this general level of inaccuracy, the bulk trends are substantiated by many studies showing the possibility of converting current acreage of tilled fields growing feed for animal consumption into grass production for animal consumption, and the large opportunity that exists to slow, stop and in time reverse the worst effects of climate change. Much more research is needed on soil health, sequestration ability and optimal sequestration techniques, and in particular the market forces to drive these changes.*

THE DILEMMA OF PASTURES AND GRASS PRODUCTION:

Given that properly managed pastures and grasslands are very good at building soil and can sequester large amounts of carbon, we are still left with a large dilemma. The dilemma is that while pastures and grasslands can be efficient at sequestering carbon, they are inefficient at producing animal protein and (excepting some perennial grains yet to be fully developed) are unable to efficiently produce other crops or vegetables that can be eaten directly by humans.

This is important because one can start managing existing pasturelands much more efficiently ("holistically") to store carbon, but once this is done, a large percent of existing cropland needs to be converted to pasture / grasslands to extend the carbon sequestration ability in order to achieve the large sequestration rates noted above, and stop topsoil losses. A huge amount of existing farmland would need to be put into pasture/ grasslands to make a material dent in US and global carbon emissions and sequestration. In the analysis performed in the previous section, converting 33% of existing croplands globally to grasslands equates to approximately 4 billion acres of farmland. The US uses approximately 60% of its farmland to produce grains for animal feed or exports for animal feeds. Ostensibly, most of this acreage should be converted to grasslands, for carbon sequestration as well as to stop topsoil losses.

Generically if 'just' 33% of agricultural land in the US were converted from grain production to grass production there would be a seven-fold to fifteen-fold net loss of productivity. This is because the food conversion ratio for ruminant that are fed grasses is much lower than if they are fed grains. When a Cow eats grass, it takes as much as 20 to 30 pounds of fodder to produce one pound of beef. On a dry weight to dry weight basis, (taking out the water weight gain) this is a 1% to 1.5% conversion rate. Grain fed cattle's FCR is in the range of 7 to 15 pounds of grain to produce one pound of beef, a dry weight conversion of 2% to 4%.

Grains fed to other animals like Chicken, Pork and Fish have better FCR's as noted below.

Product	FCR	% LB's into animal	% Dry Matter	LB's Dry Matter	WFI FCR Advantage
Fish	1.2	83%	30%	0.25	
	1.5	67%	30%	0.2	
	2	50%	30%	0.15	
Beef	7	14%	29%	0.04	603%
	15	7%	29%	0.02	
	30	3%	29%	0.01	
Chicken	2	50%	34%	0.17	147%
	5	20%	34%	0.07	
Pork	4	25%	33%	0.08	303%
	9	11%	33%	0.04	

Grasses can be fed to chicken and pork as well, but the lower FCR is equivalent to beef on a proportional basis.

Without solving for efficiency, if 33% of the world's croplands were converted to grasslands, there would be too much of a net loss in food production, even for today's population, let alone the 3+ Billion more people we will need to feed shortly. Some proponents of grass production say there is enough non-productive land or land in conservation set-asides that could be converted to grasslands and not require conversion of existing croplands. If true, this still ignores the reality that most croplands are suffering from dwindling topsoil, and needs to be converted, just to remain productive, even if carbon sequestration were not a goal.

So, the Dilemma, the equation to solve, is how to gain the carbon sequestration, and soil building advantages of grasses without losing the productivity yields of grains. Furthermore, we need to not just maintain the same rates of productivity but also increase productivity by 50% to 100% to account for population growth, a rising middle class's preference to eat more meat and other challenges to conventional food and livestock cultivation.

GRASS-BASED DIETS: A POWERFUL SOLUTION

A solution to this dilemma that is at the heart of Waterfield Farms production process is an innovation in animal feed that has been used and partially perfected over years of market-based trials. This innovation is to use grasses fortified with several inexpensive and low-carbon ingredients to build a Grass Based Diet (GBD). GBD's are a pelletized feed that is based on grasses, but has the productivity of a grain, and thus the potential to solve the dilemma of pastures and the challenges presented in this document.

GBD's are based on cutting grass** on grasslands, having that grass be used as feedstock in a feed mill to be combined with many different ingredients. So, one is not feeding grass directly, like fodder, hay, or haylage, but more of a hybrid form, which is why they are called grass based diets, *based* on grass, but not all grass. This is also commonly referred to in the feed industry as a 'Compound Feed', or a formulated feed designed for the specific nutrition of each animal it is intended for.

(** Many advocates of pastures for the use of carbon sequestration and soil restoration note that animals must be grazed on the land to generate the proper benefits. That cutting grass like hay does not have the same benefits. This is true but there is a range of techniques like simple rollers or counter-rotating rollers with hoof-imprints on them and spray-irrigation of manure solids that can simulate the same effects. This is a controversial perspective and has been preliminarily borne out by some WFI research, but more additional work is needed.)

Initially GBD's would be ~40% grass and 60% of a mix of ingredients, but over time can be expanded to as much as a 70% grass base, as experience grows with the right type and blends of grasses to grow. A 70% GBD is most likely based on haylage, but it could be on new types of high protean grasses. WFI has shown in several full production trials that a 40% GBD's grew fish as efficiently as an all grain based diet with an FCR of 2. Lab based trials on newer formulations showed FCR's as good as 1.5 compared to 1.2 of conventional diets. It is expected that these newer formulations will match conventional diets in time.

Based on a sequestration rate of 1.7 for grass, A 40% grass based GBD sequesters as much as .498 pounds or ~½ pound of carbon for every pound of a GBD that is fed. A 70% GBD sequesters .870 pounds of carbon per pound of feed fed. This becomes a very powerful metric when the billions of pounds of animal feed used every year are multiplied by the .5 or .87 pounds of carbon that can be sequestered per pound of grass based feed.

As a bit of a math check, if all the global tons of beef, chicken & pork produced (~237,292 billion tons excluding grass fed beef) are multiplied by an average FCR of 5, times .5 pounds of carbon / pound of feed fed = 6.75 billion pounds of carbon sequestered. Just a bit less than the 6.88 billion that could be sequestered by grasses noted above. This very rough calculation would need to be tuned with better data on pounds of meat raised on grain, not use an averaged FCR, etc. However, that fact that this shows the same ballpark number indicates this as another way of calculating the sequestration potential of GBD's, and maybe the accuracy of the previous calculations.

An added benefit of GBD's is not only are they sequestering carbon, but are also removing some of the carbon emissions currently produced by the livestock industry. Not counting carbon from soil losses, livestock account for an estimated 9% of global CO_2 emissions, 35-40% of global Methane and 65% Nitrous Oxide emissions.

Some advocate not eating any meat at all. This conserves grain use, but does not address the soil losses from the grain and other plants grown to make a vegetarian diet. Feeding grasses to animals and eating an all meat diet (as unhealthy as this might be) would be less carbon intensive than a vegetarian diet based on conventional grains and vegetables. If only organic grains and vegetables were eaten, a vegetarian diet would be carbon neutral to just slightly negative. This is because organic agriculture's carbon sequestration varies depending on the farmer, and at its best does not sequester as much as grasses because it still involves tilling the soil and other factors.

As an ironic twist of math, the more inefficiently a GBD is used, the higher is its carbon sequestration value. For grain diets, the more that is wasted more carbon is emitted. Of course, the efficient use of a GBD saves on money, the cost to purchase a GBD, but if a farmer can afford to waste some feed by feeding inefficient animals, they are helping to sequester more carbon. I.e. the more pounds of feed they use per pound of animal, the more carbon they sequester.

The efficiency of inefficiency aside, GBD's presents a solution to the paradox; How to pivot away from grain production on cropland and replace them with equally productive grassland that are environmentally restorative. A GBD can be tuned for most any animal, making GBD's a good alternative to replace almost all conventional grain diets, and creates a way to allow the conversion of croplands into grasslands without a net loss of the (unsustainable) grain yields we currently have. Even the controversial manufacture of Ethanol can be accommodated using the evolving possibility of cellulosic ethanol production based on grasses. However, GBD's will likely only achieve the scale needed when their costs are equal or lower than conventional feeds as discussed more below.

GRASS FED FISH, WATERFIELD FARMS & IAH:

The above Food Conversion Table shows that in spite of the sequestration benefits of wasting feed, fish are the most efficient use of any feed, but especially of GBD's. Based on an FCR of 1.2, 25% of the feed fed to a fish, becomes fish compared with 15%, for chicken, the next best converter of feed to food.

Waterfield Farms system of Integrated Aquaculture and Hydroponics (IAH) can use Grass Based Diets, or GBD's to solve the dilemma of pastures low productivity rates, and improve net food outputs above that of other animals and even that of fish alone. This can allow a net increase in yields needed to feed our increasing population.

A typical IAH system like WFI's can produce three crops, in the same vertical space, in the following volumes:

All numbers in pounds Year	1	2	3	4	5
Plants	2,278,464	3,076,668	3,685,068	6,117,234	6,141,900
Shrimp		169,833	337,000	676,000	1,135,000
Fish		2,052,241	2,052,241	4,420,505	4,420,505
Total Fish, shrimp & Plants		5,298,742	6,074,309	11,213,739	11,697,405

Some call this 'aquaponics', but aquaponics traditionally focuses ~90% on plant production and produces only a minimal amount of fish or other aquaculture crops. Aquaponics primarily uses fish to make manure in a kind of aquatic compost pile to grow plants. Integrated Aquaculture and hydroponics, IAH, produces aquatic animals in nearly the same ratio as plants. In WFI's perspective IAH is a more economically viable model because costs are spread more evenly across all crops, synergistically lowering costs and increasing net margins.

SYSTEM-FCR / S-FCR:

Due to its integrated nature of producing three crops on the feed input normally used to grow one crop, Waterfield Farms IAH system can convert as much as 55% of the feed fed to the IAH system into fish, shrimp and plants. In WFI's IAH system, waste feed from fish production are processed in several ways and fed to shrimp. The wastes from the shrimp and fish are processed further to feed / fertilize plants. The improvement in FCR yield in an IAH system is termed the System-FCR or S-FCR or the food conversion ratio of the total system.

Because of this threefold utilization or multi trophic utilization of feed, an IAH system fed a GBD can produce at least seven to fifteen times the protein of (animals grazing on) a pasture, as well as five to ten times the vegetable yield if the same pasture were plowed and planted in vegetable crops. IAH can grow vegetable and animal protein simultaneously, in the same vertical space, while maintaining the same carbon sequestration potential of pastureland/ grasslands.

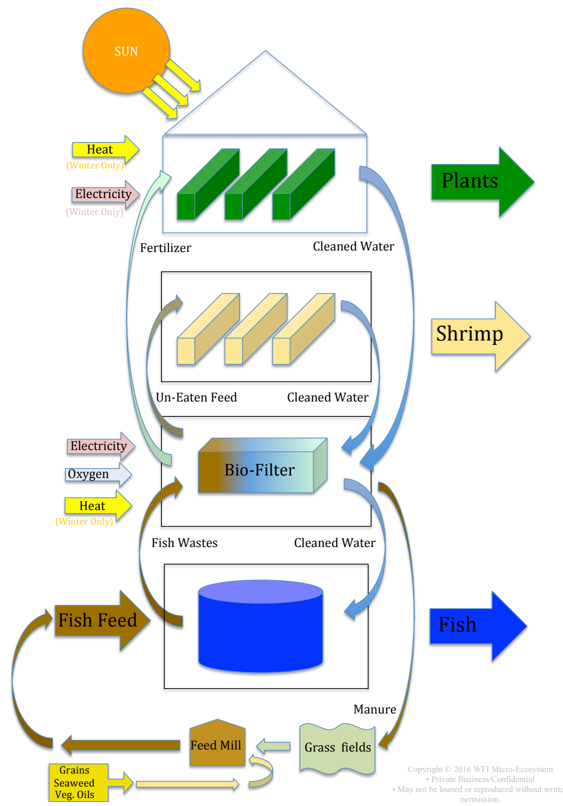
The System-FCR or S-FCR of feed fed into an IAH system:

	S-FCR	% LB's into animal	% dry mater	Pounds of dry mater produced	
IAH System	0.95	105.26%	30.00%	0.32	Current WFI configeration*
	0.55	181.82%	30.00%	0.55	Maximizing shrimp production / expanded plants ratio
	0.45	222.22%	30.00%	0.67	Maximized shrimp & adding mussels

For one pound of feed fed to an IAH system between .32 and .67 pounds of food are produced. Using the mid-level improvement of .55, even against chicken's best FCR of 2, or 17%, IAH is over a 3-fold or a 300% improvement.

This is because for one pound of feed input: (For the middle line scenario above.)
25% of the input feed becomes Fish biomass (The yield if only a fish was fed)
20% of the leftover feed from fish becomes Shrimp biomass
10% of the remaining left over feed from shrimp & fish becomes Plant biomass.
= 55% S-FCR utilization.

(* The current configuration of WFI's facility does not maximize all of the S-FCR potential as the system is designed for other factors like scaling, product marketing considerations and currently available space – but as the facility is expanded in phase II & III, the S-FCR can be maximized beyond the initial S-FCR's dry weight conversion from 32%, to as high as 67%.)



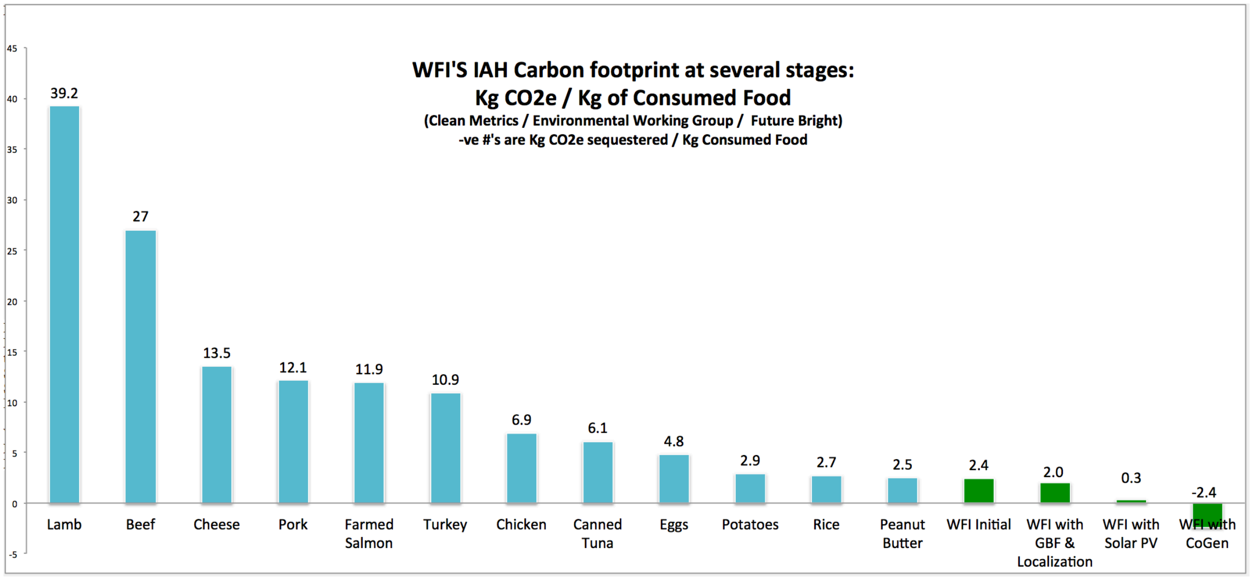
This means that 55% of the feed fed becomes food, and the 45% remainder is waste as manure. When growing beef on grass, effectively 98% to 99% of the feed fed becomes waste as manure. With the better FCR of chicken eating grains, still 83% of the feed is lost as waste manure. From these waste numbers, it also becomes easy to see why there are so many issues with manure pollution runoff, and worse, the methane emissions of anaerobically stored manure in manure lagoons. (Another benefit of IAH is the methane production in ruminants' guts that fish do not produce, i.e. no Cow-farts or Cow-burps. Because the entire IAH production cycle is kept entirely aerobic, fish or IAH production produces no methane.)

The inefficiency of cows is also what makes them so good for grasslands. For existing pastureland that may not be good for growing crops, leaving this land in pasture is the highest and best use as long as it is managed properly / 'holistically'. Because cows do not extract much, and plow (or stomp) 99% of what they eat as manure back into the ground, they can be very healthy system for working on either delicate soils, or restoring soils not strong enough to support the yields desired for producing GBD's.

CARBON NEGATIVE FOOD PRODUCTION

Waterfield Farms system fed GBD's can produce carbon negative food utilizing the carbon 'credits' from its GBD's. This is the case for any animal or system that is fed a GBD but since WFI produces so much more food per pound of carbon input, it has a very small carbon footprint. When combined with other energy saving systems, and carbon neutral energy use from PV-solar and biomass heating (or Cogeneration - CH/P) its carbon footprint goes negative. I.e. it sequesters more carbon that it consumes in its production cycles.

Added to this is what WFI calls its localization effect of not having to ship food thousands of miles, and the savings from fresher product in reduced product shrink to its customers (food rotting before it is sold) further improves WFI's negative carbon footprint. When all of these areas are counted WFI's carbon profile can be seen compared to other meat fed with grains or vegetable production.



"WFI Initial" – is WFI's carbon footprint not counting any offsets from GBD's or other factors. This is just the carbon produced per pound of food.

"WFI with GBD and localization" - Shows the carbon offset from GBD's (note this effect is not large because WFI's S-FCR is so efficient / uses such a small amount of feed. (This factor would be much larger for other animal production with worse feed efficiencies.)

"WFI with Solar PV" - Shows its electrical carbon emissions replaced by solar PV

"WFI with Co-gen" - Shows both heat and electrical carbon emissions replaced by biomass fired cogeneration system.

(Not factored in is the carbon footprint to manufacture WFI's equipment – This still needs to be calculated, but will be relatively small, and would be 'paid-off' fairly quickly by its large negative carbon yield.)

All in, WFI sequesters 2.4 pounds of carbon for every pound of food it produces. Using an FCR of 2, ~ one pound of this 2.4 is carbon sequestered by using a (70% grass) GBD, the other 1.4 pounds come from avoided carbon use relative to other food that is transported a long distance and rots faster on store shelves. Whether one counts the actual sequestered value or includes avoided carbon, for the time being, WFI's production system is the most carbon efficient form of food that is not a pasture fed ruminant like cows or sometimes chickens. But as noted, ruminants sequester so much carbon because they waste so much feed, and need much more land per pound of food making them impractical for converting cropland to grasslands, or growing more food on less land for an expanding population. This is not to say that existing pastureland should not be optimized to produce as much as possible, but once this is done, only food based on GBD's and especially GBD's fed to an IAH system can take food production, carbon sequestration and soil restoration to the scale that is needed, to make a material dent in slowing and then reversing climate change.

THE DILEMMA OF MARKETS

This document has shown that grass based production, built to scale can have a major impact on shifting climate change. And has shown how Grass Based Diets address the dilemma of the lower productivity of grasslands/ pasturelands vs. grains. However, another dilemma remains, and that is how to initiate the conversion of croplands to grasslands in the market. The initial problem is that if farmers started growing grasses as a feedstock for GBD's, there is currently no large-scale market to sell them to.

Compounding this issue, WFI knows from experience, that initially GBD's will be a bit more expensive that grain based diets, and will have 5% to 10% poorer FCR yields. Higher costs will be due to small batch milling costs, and small batches of added ingredients will not have the lower costs that volume purchases bring. Lower yields come from good but (so-far) sub optimum GBD formulations.

Some farmers may be willing to pay higher costs for a more sustainable product, but they would need to sell into the smaller niche markets that pay higher prices for sustainable and organic food. Small-scale production amongst a few dedicated farmers and consumers could slowly build the market, like has happened for the overall organic market. But the organic market has been building for the last 60 years in this style, and while growing exponentially now, is still just over 4% of the US market. We do not have the luxury of time at the moment. Topsoil reserves alone are projected to only last another 60 to 100 years; not counting the vicissitudes of climate change that will be upon us much sooner than 60 years. The revolution needed to convert to grass based farming needs to grow faster, and gain a larger market share much sooner than a slow natural growth cycle can provide.

If the federal government were to fully recognize the problem, and the solution(s), and provide funds, grass based faming could be accelerated. But our current government is unlikely to provide funds for a solution to a problem it does not yet acknowledge even exists. At the moment, market forces based on better profits are the only option to drive the innovation, at the speed and scale needed. And government supports are only useful to support faster adoption; over the long term GBD's must be sustainable in the market on an economic basis as well as an ecological one.

THE POWER OF LOWER COSTS TO MOVE MARKETS

Waterfield Farms can provide the needed catalyst to initiate this market. Because of WFI's large S-FCR efficiencies, it can afford to pay slightly higher prices for GBD's and handle the slightly lower initial FCR conversion ratio, (currently set at 2). Additionally, WFI's better labor, energy and capital efficiencies, due to handling three crops in the same facility, further lower cost. Lower production combined with very low distribution, sales and marketing costs gives WFI the ability to produce organic products and sell them at conventional food prices. Conventional prices give WFI access to a massive market, and the ability to grow very quickly.

WFI can be the first initial customer for the beginning sales of Grass Based Feeds. WFI will contract with local farmers to produce grass batches for its partnered feed-mill, initiating a market for farmers to sell to. As production experience with better GBD's grow, and WFI's scale grows through its phased expansion plan it will be able to justify a dedicated feed mill – tuned for the optimum production of GBD's. Concurrently WFI on its own, and in conjunction with several local universities will start trials for better GBD's formulations for fish as well as other species, particularly chicken, pork and dairy. Once these other diets are properly vetted, WFI can initiate GBD sales to other poultry and livestock growers, and by increasing the market size can bring GBD prices down to be competitive with grain based compound feeds.

There are several key factors WFI thinks will contribute to the rapid adoption of GBD's. The first is that the production of GBD's, once optimized, will likely be less expensive to produce than grains, because grasses have lower fertilizer and other input costs. Some of these lower costs can be passed on as a lower priced product, but some savings can be retained by farmers to give them a better net margin than they had previously growing grains. Additionally, with grasses being less susceptible to high heat and drought (becoming more common due to climate change), farmers should experience more even yields and sales than the boom and bust yield and prices occurring every few years that is becoming usual with grain markets. This higher net margin, more consistent yields and lower costs should be a strong incentive for grain farmers to convert to grass based production.

On the buyer's side, consumers of GBD's, notably, dairy, chicken, pork and finishing feed for beef, as well as aquaculture should see a net lower price per effective FCR than they currently get from grains. They will also appreciate the more even prices grass based markets should produce.

There are benefits for other 'stakeholders' in a new grass based farm economy, from equipment providers who have new gear to sell, to the end-consumer who gets a more-healthy product, with higher omega 3, and lower omega 6 ratios in their meats. Over time the groups that do not benefit from this conversion who are likely to lobby against it, should be outnumbered. At this point government incentives may be available to speed adoption.

In time, as the news and advantages of GBD spreads WFI expects other feed mills to copy WFI, and start to compete with different and maybe even better feed products. Then the race to the bottom in terms of price begins, and with low prices, the race to grow a very large market can take off. This should create a perfect-market-storm, with the production pushing for, and consumers pulling for, a conversion of grains into grasslands.

Other farmers and feed mills could take on work to develop GBD's concurrently with WFI, but to date WFI knows of no others perusing this. There is as a lot of attention to improving pasture management for carbon sequestration, focusing around 'holistic' management. This can have a major impact, but can only impact land that is not currently producing grains, as discussed regarding the dilemma of pastures.

SUSTAINING SUSTAINABILITY: THE QUALITY OF SEQUESTRATION

Some reports show that there is enough existing pastureland that could grow all the beef currently grown in the US, which would be a huge achievement. But to have it managed 'holistically' would require a market mechanism that WFI thinks does not exist yet, because the price of grass fed beef is still 40% to 60% higher than conventional beef. Because of price it will likely remain a niche market, unless and until pasture raised techniques can approach the same cost of conventionally grain fed, or grain finished meats.

Even with the development of low cost pasture production, carbon sequestration yields could vary considerably with different management styles, like is the case with organic farms. Some kind of market mechanism is needed that values an actual increase in the carbon content in soils, and a process to easily verify actual increases in soil carbon.

This is also the case for farmers producing grass for GBD's. Techniques and effectiveness of carbon sequestration will vary considerably. To address this WFI is working with a carbon credit market maker, Carbon Credit Capital (CCC) to create a needed incentive and certification program to ensure that the promise of sequestration is properly executed in reality. A key feature of this program is to incentivize, not just producers, but also consumers by allowing them to share in the value of the carbon credits. This will incentivize both sides of the market. A carbon credit program for agriculture can provide both an incentive and initial subsidy for farmers to grow grass based products, and farmers in general to lower there carbon emissions and work to sequester carbon. The uniqueness of CCC's program is it incentives the consumer to buy low carbon products as well. CCC and WFI are working to create a carbon rating system for food that can go on all consumer labels, like nutritional information.

There will be a symbol noting the amount of carbon produced or sequestered that can earn certain carbon credit points. The lower the carbon, the higher the carbon credits points allotted to that product. Buy purchasing products with the highest carbon credit points, (tentatively called 'Carbon Joules'), consumers can earn points that can either be exchanged in supermarkets for in-store promotions, or exchanged for cash in an on-line carbon marketplace created by CCC.

A key linchpin to launching this Carbon Credit, or Carbon Joules program will be the willingness of retail stores/ supermarkets to participate. The easiest way to a manage the accounting of Carbon Credits/ Carbon Joules, other than clipping label coupons, will be through supermarket scanner programs like existing loyalty cards.

Because of WFI's direct to supermarket sales program, it is in a unique position to introduce and market this program to supermarkets and other retailers. WFI intends to pioneer the Carbon Joule label and Carbon Joule credit points, and then work with climate advocacy programs to encourage other food producers to adopt the ranking of their products on the carbon content of their products. Obviously, only companies with naturally low carbon use will want to participate initially. But the absence of a rating can be as informative to consumers in there purchasing decisions. Some companies could purchase carbon-offsets to improve their Carbon Joule rating further enhancing the carbon market.

There are three key participants that benefit from this program, farmers, retail food stores, and consumers. Farmers earn credits for lowering carbon emissions, or sequestering carbon. Retailers earn carbon credits for stocking products that have adopted the Carbon Joule program. They can monetize those credits directly by cashing them in the carbon marketplace, or offering them with some improvement in there value for in-store purchases as part of there store loyalty programs. And of course, as consumers earn credits, they can monetize their Carbon Joules several ways noted above. Consumers get to feel like they can actually make a positive difference in slowing climate change while saving money. The key intent of incentivizing all three participants is to create a powerful marketplace to incentivize carbon reduction and heightened awareness in general. This can turn the immense power of consumerism to stop carbon pollution and incentivize solutions.

Concurrently with CCC, WFI is working with a company developing inexpensive soil carbon monitoring equipment. This will be a key backbone ingredient to managing a carbon credit program for agriculture because farmers as well as certifiers need an easy way to determine actual carbon sequestered. WFI is working with Flux, Inc. an innovative company that specializes in low cost environmental monitoring systems. Flux has unique experience with AI enhanced data analysis as well as crowd sourced databases. The key devise being considered is a small wheeled or tracked drone, about the size of a toaster oven, that can rove autonomously across fields, sampling for soil carbon as well as a grass crop yields and host of environmental and soil conditions. The gathered data can be used by farmers as feedback to improve their cultivation techniques to maximize yields as well as carbon sequestration. The crowd-sourced amalgamation of gathered data can be shared amongst farmers to collectively tune their practices. Depending on farmers preferences this data can be shared through public websites to create a level of transparency with consumers about the impact of their acquisition of Carbon Joules through the products they purchase.

A dilemma of using carbon-credit incentives is they are often victims of their own success; the markets for these incentives become saturated, and the prices and incentives tend to drop over time. WFI thinks these programs can be good to initiate certain practices, but after that certification of results becomes mostly voluntary based on public political support of doing the right thing for people and the environment.

WFI's idea as an ultimate solution is to publically state its goals in a marketing program for consumers to support. Lower prices, and carbon credits can drive initial consumer adoption, because they can support better food practices without having to pay more, and then based on habits, and heightened awareness and education on the issues, continue supporting (buying) carbon negative food, guided by strong certification programs.

However, some consumer education programs like dolphin safe tuna have worked well and others have not. WFI is hoping that the combination of competitive prices, initial carbon credit incentives, and a large social media program motivating consumers to choose carbon negative foods can be developed to maintain a certification program. This can keep the quality of sequestration at the rates needed to really address soil loss and climate change.

If this is not effective then some form of government regulation will be required that mandates certain minimum levels of carbon sequestration, in the same way that other pollutants are taxed, caped and traded or prohibited. Other than mandates, this is an area that a carbon tax would be very helpful, and until carbon pollution goes to low, will help extend the lifecycle of a carbon credit market. However even if the above 'hoped' for consumer driven results do not fully maintain market based sequestration and certification programs on their own, and government support is needed, WFI believes that it, and in time other producers, can generate enough support in the market and general population that the tolerance for a government mandate of some sort will be politically easier to implement.

A slightly similar analogy can be seen in the organic food movement. It took the many years of private organic certification programs work to build public recognition of organics, for the program to grow large enough, and controversial enough in terms of irregular standards for there to be sufficient public support for the USDA to take over organic certification. Theoretically standards for carbon sequestration will be much simpler; one either increases their soil carbon content or does not. Tests for this are straightforward, and will involve much less regulation than goes into Organic certification.

WFI, IAH AND GBD'S AS A CATALIST AND A CALL FOR CRITICS

This is of course a very simplified economic and market analysis, but it still shows the point that WFI can serve at least as one of the catalysts to kick off a grass based farming economy that primarily replaces grain being fed to animals. This should manage the dilemma of no current market for GBD products. Based on WFI's expansion trajectory it is plausible that commercially viable GBD's can be available for other livestock other than fish in a period of five to six years. After that, growth based on lower costs and better yields should accelerate over the next 20 years. This may be fast enough to hit the 33% grain to grass conversion target in the next 25 years referenced earlier. But it will take a massive effort; one that only a powerful market force could drive.

Waterfield Farms believes it is in the unique position to kick of a nascent market for GBD's. WFI can show the economic and ecological benefits of GBD's through its Integrated Aquaculture and Hydroponic systems better S-FCR yields, WFI's commercial success, as well as working with local universities and other early adopters of Grass Based Diets.

Lastly, WFI can see no other solution that can sequester the volume of carbon from our atmosphere like these proposed market-based solutions. Wind, solar and all other forms of alternate energy do not accomplish this, as they stop future emissions, but do not remove past emissions. To sound a bit grandiose, unless other more effective techniques are proposed, this is the only way to remove excess CO2, and prevent the worst ravages of climate change, even if humans stop emitting a net amount of CO2.

As part of a challenge to all the readers of this narrative, WFI invites critique to challenge the assertion that grass based sequestration is the only way to accomplish the reversal of climate change currently available. WFI is looking for any other alternatives that could be as powerful at sequestering atmospheric carbon at scale, affordably, with a ready market mechanism for implementation. Additionally, WFI seeks critique to point out any material mistakes or oversights that might substantially invalidate the conclusions made here. If no other solutions are proposed or material mistakes are found then it is imperative that this be pursued aggressively, as humanities' only option to preserve not just our climate, but or ability to produce food as we have known it. Only rapid action can avert the unimaginable kayos we are on the edge of tipping into.

SUMMARY

At the nexus of the solution to climate change is an intersection between science, economics and policy. Ultimately, we've shown carbon sequestration in our soils to be a powerful tool in our shared societal effort but key challenges remain. For one, there's no current market for the Grass-Based Diets to facilitate large conversions of cropland to grassland. Secondly, grass-based diets are expensive. Waterfield Farms is a market-based solution to these first two challenges. Waterfield creates the market for grass-based diets and has the embedded economics through superior S-FCR to support them.

More research is needed on soil carbon, sequestration, grass varietals, formulations and farming techniques. Waterfield Farms creates a forum for scientific and public sector partnerships to facilitate this research.

All new markets require a powerful catalyzing force, and Waterfield Farms can be just that for grass-based diets and food production that mitigates climate change risk. Waterfield already boast a market-leading ratio of Kg of CO2e emitted to Kg of food consumed. Through continued innovation and renewables integration, Waterfield becomes a model for both GBD's and carbon negative food production.

As Waterfield creates and scales the market, other farmers and producers will catch on. Consumers, too, receive a powerful leverage point for using their food dollars to improve society. Further research can be done to 'fit' grass-based diets to other livestock and as the market scales, costs come down.

All great society's great economic innovations start with a foundation stone. By creating the basis of the grass-based farming economy, Waterfield Farms enables opportunities for equipment suppliers, research organizations, a new class of grass based farmers and acts as a needed market signal for investors to take notice of the critical state of our soils, and the essential role they play in causing, and can play in solving the climate crisis.

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For the precursor to this paper and additional background on the environmental and food production challenges faced by the world, please read article written by WFI's CEO for Aquaculture magazine. "Grass Fed Fish". This describes a pretty dramatic crisis we are facing in food production, It is a pretty massive problem, but also an equally large opportunity. Clicking on the below link will download a PDF copy of the article "Grass Fed Fish": "Grass Fed Fish V14sC.pdf" https://eepartners.egnyte.com/dl/P5nWFkKQyr