Plant-Based Diet:
Inseparably Linked to Health and ESG

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Dear readers: Please feel free to forward this article to anyone interested in adopting the plant-based diet and environmental protection. If you have any inquiries about this article, please email caseykclim@outlook.com. Readers are welcome to use this article for the purpose of providing education on the importance of the vegan diet.

I hope this article could serve to motivate more people to explore the vegan diet. It puts forward the case that the vegan diet is good for health and the environment. A person considering a diet change should also take into consideration psychological factors such as a possibly smaller social circle, acceptance of the vegan diet by one's spouse or dating partner, family members, etc.

Wish everyone excellent health, peace and happiness!

Thank you, Casey

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"选择营养均衡的纯素饮食，疾病会远离您"
("Choose a balanced vegan diet and illnesses will stay far away from you")

Note to all readers:

i. This article, *Plant-Based Diet: Inseparably Linked to Health and ESG* is focused on the environmental and health benefits of adopting the vegan diet. This article is essentially a shortened version of *Plant-Powered Diet: A Journey for Health and the Environment.* There is a brief explanation in this article as to why most Buddhists who are on a vegetarian or vegan diet do not consume garlic, onions, spring onions, leeks and chives.

   This article has left out a substantial amount of content related to Buddhism and the author's interpretations of the Buddhist thinking on the vegan diet. This is to enable information on the environmental and health benefits of the vegan diet to be made more accessible to a wider audience. Reading content on Buddhism may be against the religious practices of certain individuals. Also, some individuals may not wish to read about content that is related to Buddhism and are interested only in the science behind the vegan diet.

ii. Readers who wish to find out more about the author's Buddhist interpretations and personal views on the vegan diet may refer to, *Plant-Powered Diet: a Journey for Health and the Environment.*

iii. Any recommendations or advice given in this article cannot replace the advice that is provided by nutritionists and qualified doctors.

iv. I strongly encourage all to seek medical advice from their respective registered doctors and/or nutritionists before they adopt the vegan diet.

v. I do not support self-medication for those who are not feeling well, and I will certainly visit a medical doctor if I am sick. I advise all to seek medical advice as well if they do not feel well.

vi. If you are unwell, you may have to take sick leave. I will certainly take sick leave to get a good rest if I am unwell. I advise all to seek medical advice if they do not feel well.

vii. The content, comments, opinions and views expressed herein are solely my own and do not necessarily reflect the views of any entity, company or organization.

Possible conflicts of interest: The author may set up companies to provide plant-based foods and invest in securities of companies that are involved in selling plant-based foods and services.

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1. Introduction

This article puts forward the case that the plant-based diet is inseparable from health and the Environmental, Social and Governance (ESG) standards. A vegan diet, also known as a plant-based diet, does not include any animal products. Those who are on a vegan diet do not consume meat, seafood, dairy products and eggs. My personal belief is that a well-balanced vegan diet is inseparable from good health. In this article, I provide supporting findings from research publications to show that the vegan diet is good for the health of the general population.

Data from 2001-2020 show an upward trend in total renewable energy generated globally.[1] The main sources of renewable energy include hydroelectric, solar and wind power. Total energy generated from all renewable energy sources in 2001 was about 2,815 terawatt-hours. In 2020, renewable energy produced amounted to 7,444 terawatt-hours.

The energy generation from solar and wind power as a proportion of total renewable energy generated grew from about 1.4% in 2001 to about 33% in 2020. Solar energy generated in 2001 was only 1 terawatt-hour but had increased to about 856 terawatt-hours in 2020.

The upward trend in the total energy generated from renewable energy sources is expected to continue as new investments in renewable energy projects across the globe continue to fight against global warming. Technologies are being developed to reduce the emissions of greenhouse gases and remove the greenhouse gases now existing in the atmosphere. All these avenues are of course much welcome and needed.

Another means to combat global warming is the more widespread adoption of the vegan diet across the globe. The evidence is overwhelming that a plant-based diet is an indispensable tool. The estimates of the incremental emissions of global anthropogenic greenhouse gases from animal farming range from 14.5% to 20%. These are very high estimates and the more widespread adoption of the vegan diet for all of a person's meals certainly goes a long way to help Earth combat global warming. The vegan diet also leads to a reduction in the pollution of freshwater.

This article reviews the research findings and data presented by others to provide support for the principle that the vegan diet and ESG are inseparable. Recommendations to the governments, corporate leaders, universities, medical schools, medical associations, etc. are provided. The environmental damage from animal farming is well known and has been highlighted in numerous publications, including reports by the Intergovernmental Panel on Climate Change (IPCC). Hence, the case that adopting the vegan diet is related to the "E" in ESG or the environmental standards is nothing new.

This article hopefully could motivate more firms, schools, universities, financial institutions and governments to actively inform people about the benefits of the vegan diet as they go about advocating ESG. It brings together the latest findings on the health benefits of adopting the vegan diet as well as the details of how animal farming adds to the environmental damage that Earth is currently facing.

The number of people globally on the vegan diet is still tiny currently and I hope that this article adds to the body of articles on the benefits of the vegan diet. I am presenting my experience with a plant-based diet as a case study too. I hope that readers could use the information provided and decide for themselves whether the plant-based diet is appropriate for them. The aim is to enable more people to have the relevant information for their health.

The kitchen table is a powerful avenue through which people across the globe could participate in to achieve the target of reducing global temperature rise to below 1.5°C from the pre-Industrial Revolution era. Given that the incremental reduction of greenhouse gases via adopting the plant-based diet is significant, it is clear that the plant-based diet is an important component to strengthen the 'E' in ESG. To me, the vegan diet and ESG are inseparably linked.

The vegan diet has gained increasing acceptance but its adoption is still currently not sufficient to make a significant dent in the emissions of greenhouse gases. Meat consumption is projected to grow from 324 million tons in 2020 to between 460 to 570 million tons in 2050, a staggering increase of between 42% to 76% from the 2020 level if the global appetite for meat does not change. [2] [3] The world population has to drastically cut down on meat and transform their meat-based diet to one that is much heavier in plant-based food items or a 100% plant-based diet.

While a 100% plant-based diet across the globe is ideal, it is not achievable. A more sensible strategy is to strive for a dramatic reduction in the growth of meat consumption. Given that there are benefits to the environment, a valid question that everyone should ask is whether a plant-balanced diet is healthy. Based on testimonials from vegans and research that has been published in medical and nutrition journals, a plant-based diet is healthy and is generally a powerful tool for preventive medicine. In this article, I summarize the research findings from medical and nutrition journals on the health benefits of adopting the vegan diet. I show based on past research and available data how the widespread adoption of the vegan diet across the globe will undoubtedly lead to a healthier population.

The question as to whether the vegan diet is healthy is largely resolved based on the evidence provided in journal articles, some of which are listed in this article. But to go a step further, is the plant-based diet healthier than the meat-based diet? Given the research findings, the plant-based diet appears to be healthier than the meat-based diet. The risks of contracting certain chronic diseases for someone on a plant-based diet are much lower compared to a meat-based diet. But the plant-based diet must be well-balanced. Testimonials from vegans further add to the growing body of evidence that a well-balanced plant-based diet is healthy.

Companies and financial institutions which are at the forefront of socially responsible investing should consider taking a more proactive role in the dissemination of information on the pros and cons of the vegan diet to its workforce, including senior management. Governments, international agencies, schools, universities and medical schools could also devise campaigns to provide the information on what constitutes a well-balanced plant-based diet, list its benefits, and point out certain guidance notes like the need to take vegan Vitamin B-12 supplements.

Those in leadership positions and who are at the top levels of a firm and administration can lead the way to bring this information to a much wider audience and let the people decide. As for the role of government, the government should not favor any firm or be biased unfairly toward any sector of the industry. The government should of course not favor the plant-based (meat-based) industry over the meat-based (plant-based) industry. The government's role is to provide the information and let the people decide for themselves.

This article describes my experience as a vegan and adds to the pool of case studies of those who are on a plant-based diet. My experience and research findings on the health benefits of a vegan diet will hopefully provide some confidence for those who wish to embark on a plant-based journey.

For those who wish to know more about my personal philosophy on the vegan diet and how Buddhism is related to the plant-based diet, you may refer to, "*Plant-Powered Diet: A Journey for*

Health and the Environment" which covers sections 2 to 17 in this article (there are some differences in section numbering between the two articles) and the topics, "*Farm Animals Have No Choice"*, "*My Personal Philosophy with Regards to the Vegan diet and Buddhism",* and *"Treating Fellow Human Beings and Compassion for Animals"* that are not found in this article. The topic, "*Social Circle, Gatherings and Vegan diet"* in this article is an abridged version so as not to touch on some of my personal views related to this diet.

2. My Plant-powered Journey

I have been very fortunate that I have not taken a single day of sick leave for the past nineteen years. I hope that this can continue for some more years. Nineteen years ago, I began my journey on a plant-based diet (vegan diet and plant-based diet are used interchangeably throughout). I feel very blessed that I have not suffered from any major diseases like diabetes, heart-related issues, low or high blood pressure, etc. My good health enables me to bring up my son, Darren, to keep on doing what I like to do and carrying out my current and past job duties. Darren is now in his mid-20s. I attribute my good health principally to my vegan diet.

I hope that all those who are not on a balanced vegan diet seriously consider doing so and read the relevant articles. A vegan diet is an important driver in preventive medicine but the diet must be well balanced. Another important benefit of the widespread adoption of a plant-based diet is environmental protection.

I strongly believe that in general, all people will be able to benefit enormously from a well-balanced vegan diet. For those who are presently suffering from diabetes, heart-related diseases, etc., I encourage you to seek the help of a medical doctor or nutritionist if you wish to adopt the diet.

For those who are suffering from hereditary, congenital and genetically linked diseases, it is worthwhile to talk to your doctor about diet and nutrition to see if certain diets can aid in controlling the severity of some of these diseases. Some people are suffering from genetically-linked diseases and more research should be undertaken to see if diets can help people suffering from certain genetically-linked diseases. A well-balanced vegan diet should be one of those diets that should be considered.

Everyone is different and the wonderful health benefits that I have experienced so far may not apply to others. Some doctors and specialists may not be informed about nutrition and the benefits of vegan diets. Medical schools and medical associations have a major role to re-educate doctors and specialists on the benefits of a well-balanced vegan diet, especially as one of the tools for preventive medicine. The possible disadvantages, if any, of a vegan diet as the daily diet for those suffering from certain illnesses are worth examining further.

3. My Health

I presently do not have any chronic diseases. I feel very energetic and am able to do the usual daily tasks and job duties. Based on my lab tests and medical examination in January 2020, all my indicators were normal except for the level of Vitamin D. My Vit D level was on the low side as I usually wear long pants and did not wear shorts or tee shirts when I was out during the daytime. I have since tried to put on shorts and tee-shirts as much as I can to get some sunlight for the production of Vit D. I now take vegan Vit D supplements almost daily. I try to follow the doctor's recommendation to wear shorts and short-sleeve shirts, preferably, with tiny holes, for about 30 minutes daily - 10 minutes each in the morning, mid-afternoon, and from about 4 to 5 pm.

My vision, both day and night, is very good. I did have a headache and mild fever for about a day when I was vaccinated with the Astra Zeneca vaccine in 2021. Other than that, I had minor headaches perhaps twice so far over the past nineteen years and these incidents lasted for less than 30 minutes. I think the number of Panadol pills that I had consumed over the past nineteen years was at most twenty.

My major health check indicators that showed normal readings include blood pressure, blood sugar level, cholesterol levels, etc. I get a running nose on some days, particularly in the morning. If I do get

it, it lasts on and off for about 20 minutes. I am allergic to pollen. During pollen seasons, I would get a running nose for the whole day on some days but fortunately, it was controllable and manageable.

My eyesight is very good and I have no difficulty seeing at night. My vitamin B12 level is good too, within the normal range. I take vegan Vitamin B12 supplements regularly. I went for a health check-up in December 2021 and I was certified fit for work by a medical doctor.

4. Components for Good Health with Vegan Diet as the Core Input

A vegan diet is of course not the only input for good health but it is a crucial component. To enjoy good health, we need money to buy food, clean water, clean air, a healthy environment with safe levels of radioactive radiation, support from family and friends, moderate exercise, some skills to manage stress and to be on a healthy diet. Genetic makeup is a factor too.

What then is a healthy diet? For me, it is undoubtedly the vegan diet. A number of papers published in medical journals emphasize that the vegan diet can help in lowering the probability of contracting chronic diseases like diabetes, heart-related diseases, certain cancers, etc.

It was in October 2002 when I first adopted the vegan diet. I was 41 then. Other than the mild fever from the two doses of Astra Zeneca vaccinations that I obtained in 2021, I did not have other bouts of fever since 2002.

For the past nineteen years, the only serious illness that I had was having a dry cough for about ten days in October 2019. Over that period, I took some cough tablets and about three spoonfuls of cough mixture. I went to work and had the energy to do work but my productivity though was not as high as when I was without any cough. The cough started when I was about to leave for Beijing from Sydney. I made the trip to attend the graduation ceremony for my students from the Macquarie University Master of Applied Finance program. The ceremony was at a hotel in Beijing. I was on stage as my students received their degree scrolls. I was lucky I was able to control my cough and running nose. Fortunately, I did not make any sound of coughing or sneezing while I was on the stage.

Even though I did not have any chronic diseases for the past nineteen years, it is a false notion that vegans will not suffer from any chronic diseases. Individual cases differ. The types of foods that someone on a vegan diet consumes matter. If it is just relying on vegan potato chips primarily as part of a vegan diet regime, that obviously will not work. Another issue is the age at which one begins the vegan diet. The composition of the diet and the amount of non-plant-based food intake before one begins the vegan diet are also important factors.

Alcohol consumption and smoking certainly affect the health of a person. To me, a combination of alcohol, smoking and meat will make matters worse. Those who are on a vegan diet should monitor their alcohol intake. Those who smoke should think of quitting. I do not drink much alcohol and I do not smoke. The total amount of alcohol I had consumed in the past is at most ten glasses since I reached the legal age to drink. I would take sips of alcohol to give a toast during weddings and birthdays.

The amount of meat one consumes in the past is also a factor. Even if some people had consumed a large amount of meat in the past, it is of course not too late to consider adopting the vegan diet, with the help of a nutritionist and/or medical doctor. The environment the vegan lives and works in etc. is also part of the equation. A cleaner environment with good air and water is a plus.

I like to briefly touch on the other factors that are essential for good health. Possessing money to buy food is a factor. Indeed, many people are still struggling to find money to buy food. Governments and aid agencies play a critical role to get food to people. Sound national economic policies and anti-corruption efforts are needed to raise the income of people.

Getting clean water is still a challenge for many people. Clean air and clean water are the responsibilities of governments, industries, and to a certain extent consumers too. Consumers have a role to recycle plastic products, batteries, etc., and conserve water and energy. Air pollution is a very serious health hazard in some cities and the benefits of being on a vegan diet are very much outweighed by the very serious adverse health effects brought upon by severe air pollution.

Radioactive radiation is always present in the environment from natural minerals and man-made sources, e.g., X-rays, coal-fired power plants, etc. Dangerous levels of radioactive pollution can cause deaths and harm a person's health. Past cases of severe radioactive pollution include the Chernobyl Nuclear Plant disaster in Ukraine (1986), the Fukushima Nuclear Plant disaster (2011), and the Techa River highly hazardous radioactive waste incident (1949)[4].

The ability to handle daily stress in life is crucial. It might be due to stress from work or family, or a combination of both. A very stressful situation at the workplace, e.g., is working with a very abusive supervisor. Over the years, I have had conversations with close relatives, friends and ex-students who have had abusive immediate supervisors.

The usual behavior of the abusive supervisors is to lord over someone as if they are 100% perfect and can do no wrong. It is fine to be demanding but the supervisor's role is to provide guidance, encouraging words and emotional support too. Certainly, there are better ways to do a job task and mistakes, if any, should be pointed out. There are tactful and proper ways to talk to colleagues about certain ways to do things better. Supervisors who cannot perform these roles in a caring manner and are not willing to find out the facts should never assume leadership roles.

The abusive supervisors are living in another world as they themselves have also made mistakes in their job tasks. Other forms of behavior include jumping to conclusions about one's actions and character, and assigning blame without looking into all the facts. Supervisors should look at matters also from the perspectives of colleagues and think from the angle of their colleagues in certain situations. Supervisors should gather enough information that others and possibly they themselves could be responsible too for certain errors and blunders.

The abusive language that the supervisor used can be very damaging in a workplace environment and some supervisors are unfortunately happily doing that. I heard of relatives and friends informing me of four-letter words being used at the workplace, and subtly emotionally damaging words being hurled at subordinates either verbally or in emails. Sexual harassment at the workplace is a major problem for quite a few people, particularly ladies. Victims have to endure immense stress. Those who are at the most senior levels should be aware of the abuse that is going on. Some are aware but they are not taking action.

A spouse may be in an abusive marriage. Either the wife or husband may use abusive language or engage in violence. Children using drugs may be creating stress for their parents. I encourage all to talk to their friends, relatives, and someone qualified (like a psychologist or psychiatrist if necessary) if they are being abused and see if there is a way out. Reporting to a higher authority in a firm or filing a police report in cases involving violence may be other avenues they can look into. As this article is on the plant-based diet primarily, dealing with abusive supervisors or family stress is another article for

the future. I am touching on this briefly as good health also requires other inputs in addition to a healthy vegan diet.

5. Research on Meat-Based Diet

Several articles and health websites advocating for a meat-based diet argue that meat is an important component of a well-balanced diet. The common thread for supporting meat in a person's diet is that meat is a source of proteins, iron, Vitamin B12, other vitamins, and essential minerals like zinc, selenium and phosphorus. For a sample of the findings on various research issues on meat-based diets, refer to de Castro Cardoso Pereira et al. (2013)[5], Binnie et al. (2014)[6], McNeill (2014)[7], and Wyness (2016)[8].

Given these conflicting research findings, it is not surprising that several nutritionists and doctors may disagree with the findings that the vegan diet is a tool for preventive medicine. Quite a number of people are already used to eating meat and the meat-based diet is very much ingrained in their daily lives. To many, a diet that includes meat and seafood is already a way of life. It is not easy for them to get off the meat-based diet given what has been passed on for generations that "meat is an essential part of one's diet".

My personal view is for all to seek appropriate medical advice on their diet. I recommend that those in health-related professions including doctors, nutritionists, nurses, etc. review the relevant literature on the vegan diet so that they could provide a more comprehensive set of advice for their patients or clients. To me, a well-balanced vegan diet is healthy but further research is needed to examine whether certain people may not be suited to the vegan diet, if at all.

6. Research on Vegan Diet

Based on past medical research, a balanced vegan diet can drastically reduce the probability of contracting a chronic disease like diabetes, some cancers, heart-related problems, hypertension, etc. It is not realistic to talk about avoiding sickness altogether if one were to be on a vegan diet.

I was lucky that I was able to avoid chronic diseases on a vegan diet thus far. The main goal for all is to stay healthy and avoid contracting chronic diseases. More research should be conducted on whether a balanced vegan diet could boost immunity to fight against pandemics like Covid. My healthy medical record provides me more confidence to write my story and hopefully could encourage more people to take a closer look at the vegan diet.

Based on past medical research, the vegan diet changes the behavior of genes for the better and significantly reduces the risks of contracting the following diseases:

6.1 Genes Behave for the Better with Vegan Diet

Elizabeth Blackburn, the 2009 Nobel Prize in Physiology or Medicine co-winner, and Dr. Dean Ornish find that 500 genes change in behavior for the better in only three months with a plant-based diet.[9] [10] This is a pathbreaking study and deserves more awareness among health officials, politicians, teachers, parents, etc. They find that a plant-based diet and lifestyle changes that include exercise and stress reduction turn on the genes that prevent diseases like cancer and turn off genes that cause breast cancer, heart disease, and prostate cancer. It should be noted that a person cannot get different genes but one can change how the genes act through one's lifestyle and diet.

6.2 Cancer

According to WHO[11] [12], processed meats including ham, bacon, salami and frankfurts belong to Group 1 carcinogen, which means there is strong evidence these foods cause cancer. In its unprocessed form, red meat, such as beef, lamb and pork, has been classified as a Group 2A carcinogen. Group 2A carcinogen means these foods probably cause cancer. The fact that meat in its processed form is a carcinogen has been well established. Meat, in its unprocessed form, probably causes cancer.

The probability of contracting colorectal cancer, breast cancer and prostate cancer is very much reduced for those who are on a vegan/vegetarian diet:

6.2.1 Colorectal Cancer

The relationship between colorectal cancer and diet has been a subject of interest in medical research. Orlich et al. (2015)[13] using cohorts from a study that spans about 7.3 years find that those on a vegetarian diet as a group which includes participants on a vegan, lacto-ovo vegetarian, pesco-vegetarian and semi-vegetarian diet have a 43% lower risk of contracting colorectal cancer than those who are on a non-vegetarian diet.

A future study that has a larger sample size of vegans that spans a longer period will provide a better understanding of the relationship between the risks of contracting colorectal cancer and those who are on a vegan diet and a non-vegan diet. This study however provides support for the relationship that those who eat meat on a lesser frequency and with a lower intake amount have lower risks of contracting colorectal cancer.

6.2.2 Breast Cancer

Toniolo P. et al. (1989)[14] in an NYU Cancer Institute study find that breast cancer patients ate more meat, cheese and butter than women without breast cancer. They find that those who consumed a larger amount of animal products had as much as three times the breast cancer risk of those who consumed less.

6.2.3 Prostate Cancer

Tantamango-Bartley et al. (2015)[15] find that those who follow a vegan diet are 35% less likely to suffer from prostate cancer than those who follow a nonvegetarian, lacto-ovo-vegetarian, pesco-vegetarian, or semi-vegetarian diet.

6.3 Non-Cancer Diseases

With a vegan diet, the probability of suffering from heart-related diseases and diabetes is significantly reduced. The probability of contracting diabetes is significantly lower with a plant-based diet. Vegans who contracted the covid-19 virus have less severe symptoms according to a recent research study. Maintaining good eyesight is easier on a vegan diet.

6.3.1 Heart-Related Diseases

Papier et al. (2021)[16], present systematic evidence to also show the link between consumption of meat and other non-cancer diseases. The authors, after adjusting and controlling for factors like smoking, alcohol consumption, body weight, and other factors, show that higher

consumption of unprocessed red meat and processed meat is linked to a 15% higher risk of ischaemic heart disease (heart diseases caused by narrowed heart arteries).

A reason put forward for the higher risks of heart diseases is that eating meat increases a person's bad cholesterol, i.e., low-density lipoprotein (LDL) cholesterol. High-density lipoproteins (HDL) are sometimes called the "good" cholesterol. LDLs and HDLs are combinations of fats and proteins.

Excessive amounts of LDLs in the blood may build up as plaque in the walls of one's blood vessels. If it increases over time, the arteries will get more blocked. Blood flow will be restricted and this may lead to a heart attack or angina which is a type of chest pain caused by reduced blood flow to the heart.

There is no cholesterol in plant-based foods. Cholesterol is found in meat, dairy and eggs.

6.3.2 Diabetes

Papier et al. (2021) also show that unprocessed red meat and processed meat are linked to a 30% higher risk of diabetes. On poultry which is considered white meat, 30 grams of higher poultry meat intake per day was associated with a 14% greater risk of diabetes.

In an NUS study, Koh et al. (2017)[17], find that there is a link between the amount of red meat and poultry consumed and the risks of developing Type 2 diabetes. The participants in the study were divided into four quartiles according to their red meat and poultry intake. The top quartile with the highest amount of red meat and poultry intake shows a 23% and 15% increase respectively in the risk of contracting diabetes compared with those in the lowest quartile of red meat intake.

Some studies examine the association between intake of heme iron and the risk of contracting Type 2 diabetes. Heme iron is only found in animals while non-heme iron is found in both plants and animal products like eggs and dairy. Based on a meta-analysis (i.e., an analysis that utilizes results from various research studies), Shahinfar et al. (2022)[18] show that there is a 20% increase in the risk of Type II diabetes with higher heme iron intake.

Li et al. (2020)[19] suggest that higher dietary intake of heme iron particularly from red meat is associated with a greater risk of contracting type 2 diabetes in middle-aged and older adults. Further Li et al. (2020) show that non-heme iron is not associated with a higher risk of contracting Type 2 diabetes.

These studies show that heme iron intake which is found in meat is associated with a higher risk of Type 2 diabetes. Given the results of these studies, one should examine very carefully before taking iron supplements that are made of heme iron. It is best to talk to a pharmacist, nutritionist or doctor before taking iron supplements and inform them of the results of these studies.

There are molecular differences between heme iron and non-heme iron but an important difference between these two types of iron is bioavailability. In general, bioavailability refers to the rate at which the human body absorbs nutrients. Heme iron is absorbed at a faster rate than non-heme iron. That does not mean that non-heme iron is not as good as heme iron. Non-heme iron poses a lower risk of iron toxicity given its lower absorption rate.

6.3.3 Chronic Kidney Disease

Chronic Kidney Disease (CKD) is characterized by a gradual loss of kidney function.

Kim et al. (2019) present evidence that those who are on a healthy plant-based diet have lower risks of contracting CKD.[20] A healthy plant-based diet includes whole grains, fruits, vegetables, nuts, legumes, and tea. They recommend against the inclusion of less healthy plant-based diet food items such as refined grains, sugar-sweetened and artificially sweetened beverages, sweets and desserts. They find that adhering to a healthy plant-based diet reduces the decline of the kidney's estimated glomerular filtration rate (eGFR). eGFR is a measure of the kidney's ability to filter waste and toxins in a person's blood.[21]

Joshi et al. (2020) recommend a plant-based diet for both primary and secondary prevention of CKD.[22] Primary prevention refers to preventing disease before it strikes. Secondary prevention is about managing and reducing the impact of a disease that has occurred in a patient. They state that the risk of potassium overload (i.e., hyperkalemia) that medical professionals usually associate with plant-based diets is not justified.

Cases et al. (2019) argue that a plant-based diet offers health advantages to those who are suffering from chronic kidney disease. The plant-based diet coupled with professional nutritional advice is safe for these patients.[23]

6.3.4 Lower Severity of Covid-19 Symptoms and Vegan Diet

Based on data from six countries, Kim (2021)[24] find that those who are on plant-based diets or pescatarian diets were linked with 73% lower odds of experiencing moderate to severe covid-19 compared with those who follow protein-rich, low-carbohydrate diets. The protein-rich, low-carbohydrate diets refer to higher intakes of animal proteins like poultry and red meat and processed meats. This study is important as it provides evidence that plant-based diets or diets that are low in poultry, red meats and processed meats serve as protection against the severe form of Covid-19.

6.3.5 Eye Diseases

To maintain good eye health, I strongly recommend a well-balanced plant-based diet based on my experience so far. Good eye health can be maintained on a well-balanced vegan diet.[25] Fruits and vegetables are good for eye health and reduce the risks of acquiring certain eye conditions and diseases. The eye conditions and diseases include macular degeneration, night vision, age-related degeneration, dry eyes, UV damage to the eye, cataracts and glaucoma.[26] Carrots contain Vitamin A and are rich in carotenoids. Carotenoids are also found in fruits and other colored vegetables.

Carotenoids are required by our body to make Vitamin A. Vitamin A, Vitamin C and zinc are important to help reduce the risk of cataracts and macular degeneration.

Macular degeneration is an incurable eye disease. The macula is part of the retina and its function is to provide sharp, clear and central vision. The antioxidants lutein and zeaxanthin found in broccoli, kale, spinach, peas, and lettuce help to preserve the macula. Higher intake of bioavailable lutein/zeaxanthin is associated with a long-term reduced risk of advanced AMD.[27] Given that some other carotenoids are also associated with a lower risk, a public health strategy aimed at increasing dietary consumption of a wide variety of fruits and vegetables rich in carotenoids may reduce the incidence of advanced AMD.

Vitamin C is also essential for retina health. Vitamin C can be found in fruits and vegetables. Vitamin E is an effective antioxidant that protects the eye from harmful free radicals. Free radicals are unstable atoms and can harm the cells in the human body. Plant-based foods that contain Vitamin E include almonds, peanuts, hazelnuts, pine nuts, sunflower seeds, wheat germ, and red bell pepper.

I strongly recommend all to wear sunglasses when we are out during the daytime. Sunglasses protect our eyes against harmful ultraviolet (uv) radiation. UV rays damage our eyelid, cornea, lens, etc. So, do wear sunglasses when you are out in the sun in any season. Those sunglasses with UV 400 protection are highly recommended as they block nearly all light rays with wavelengths up to 400 nanometers, i.e., nearly all UV light.

The conversion of meter to micrometers and nanometers is as follows: 1 meter = 1 million µm or micrometers; 1 meter = 1,000,000,000 nm or nanometer; 1 µm = 1,000 nm.

Sunglasses lower the risks of getting cataracts, photokeratitis, and growth masses in the eyes like Pinguecula and Pterygium.[28] [29] A cataract refers to the cloudy area in the lens of the eye. Photokeratitis is akin to sunburn affecting the cornea. A pinguecula is a yellowish, raised growth on the conjunctiva.

A pterygium refers to a growth of fleshy tissue containing blood vessels that may start as a pinguecula and may grow large enough to cover part of the cornea. The cornea is the outer transparent part of the eye and covers the iris, pupil and the anterior chamber of the eye. It refracts light and helps our eyes to focus. The conjunctiva is the clear tissue that covers the outer portion of the sclera and the inside of the eyelids. The sclera is the white part of the eye.

6.3.6 Constipation

Lee et al. (2016) find that switching from a diet that includes meat, referred to as a "normal" diet in Lee et al. (2016), to a diet rich in fruits and vegetables leads to lower incidences of constipation.[30] The subjects who participated were on a vegetarian diet over a 12-week period.

I could add to this issue based on my own experience with the issue of bowel movements. My digestive system gently "wakes" me up almost every morning, prompting me to go to the restroom. I have no issue with this, and it has been a daily morning activity for me. I drink water as soon as I get up, and this helps.

Those who are on a vegan diet eat fruits and lots of vegetables. All these foods are loaded with fibers that gently move our consumed foods along the digestive tract more smoothly. However, those on a vegan diet should take more liquids given that vegans consume more fibers – it can be water, juices or soup. It is also advisable not to take copious amounts of water or liquids immediately after or during a meal. This can lead to bloating and indigestion for some.[31]

It is alright to take sips of water during a meal and immediately after meals but not too much, say about a glass.[32] It is advisable to take more liquids, preferably lukewarm, about an hour after a heavy meal. However, do not overload with too much pure water as it can lead to hyponatremia, a condition arising from exceedingly low levels of sodium in a person's blood.[33] I take soup, drink juice or tea, and do not necessarily consume water only.

I do get stomach upsets, but luckily about once or twice a year. I just had to go to the toilet to unload and I would be alright after a few hours. It is certainly possible to get food poisoning from vegetables and one is advised to take the usual precautions such as not consuming vegetables after the expiry date.

7. What about Milk and Eggs?

There are conflicting research results on whether milk and eggs harm a person's health.

7.1 About Milk

The essential nutrients in milk include calcium, Vitamin D, Vitamin B12, proteins, Vitamin K, potassium, etc.[34] These nutrients can be found in plant-based food items or supplements. Research findings are conflicting on whether milk harms a person's health.

Thorning et. al (2016) support milk as part of one's diet and argue that milk consumption is associated with reduced risks of childhood obesity, neutral or reduced risks of Type 2 diabetes, reduced risks of cardiovascular disease such as stroke, and is beneficial for bone mineral density. Further, they argue that milk and dairy intake is "inversely associated with risks of colorectal cancer, bladder cancer, gastric cancer, and breast cancer, and not associated with risks of pancreatic cancer, ovarian cancer, or lung cancer, while the evidence for prostate cancer risk was inconsistent". They find no support for a relationship between milk consumption and mortality risk.

Fraser et al. (2020) however find that a higher intake of dairy milk is associated with higher risks of contracting breast cancer.[35] [36] Drinking one cup of milk (8 ounces) a day increases the risk by up to 50% and consuming two to three cups a day increases the risk further to 70 – 80%. A notable finding is that the risk of contracting breast cancer is 30% for those drinking as little as 1/4 to 1/3 cup of dairy milk. Fraser et al. (2020) suggest that the link between dairy milk and cancer could be attributed to the sex hormones in milk such as estrogen and progesterone, and serum insulin-like growth factor-1 (IGF-1) in milk. While quite a number of researchers and medical professionals argue that the levels of estrogen and progesterone are small in milk, low-fat milk and whole milk promote mammary tumour growth in rats.[37] [38]

A growth factor is a natural substance found in the human body and food items, and it helps to promote growth and development. Insulin-like growth factor (IGF) is a growth factor that is structurally similar to insulin. Insulin is a hormone produced in the pancreas and it helps to regulate the amount of glucose in the blood.

There are two principal forms of IGFs, i.e., IGF-1 and IGF-2. IGF-1 is a hormone that regulates growth in adults and helps to maintain and manage blood sugar.[39] IGF-1 is primarily produced by the liver. IGF-1 and IGF-2 are named insulin-like as their functions are similar to insulin and are involved in glucose metabolism. IGF-2 is different from IGF-1 in that IGF-2 is a major growth factor in the fetus. IGF-2 is produced in a variety of somatic cells (all of the cells in a human body except sperm and ova) during fetal development and in the liver after birth.[40]

1 in 8 women in the USA will develop breast cancer per year. The research findings by Fraser et al. (2020) deserve attention from doctors and others in the medical profession. Fraser et al. (2020) find no clear association between soy intake and breast cancer.

Higher levels of IGF-1 are linked with an increased risk of developing cancer.[41] Milk contains IGF-1 and certain substances in milk may trigger the production of IGF-1 in the body.[42, 43] I hope there will be more research in this area on the veracity of these findings. Romo Ventura et al. (2020) measure IGF-1 in blood samples against milk intake and find that higher intakes of milk are associated with higher concentrations of IGF-1.[44] Kakkoura et al. (2022) find that a higher dairy intake increases the risks of developing cancers, particularly liver cancer, female breast cancer, and possibly lymphoma.[45] Dairy intake was not segregated into milk, cheese, yoghurt, etc. in their study.

The possible explanations that Kakkoura et al. (2022) put forward include the following:

- IGF-1 in milk is associated with several cancers including breast cancer.
- There are substances in milk that could activate mechanisms that lead to growth in cancer cells.
- The saturated fatty acids (SFA) and trans-fatty acids from dairy products are linked with insulin resistance and increased levels of proinflammatory cytokines (which are possible risk factors for liver cancer and lymphoma).
- Sex hormones in milk such as estrogen and progesterone likely have a role.

Saturated fatty acids are one of the two major categories of fat and it is advisable to limit the intake of saturated fats to reduce the risks of contracting heart-related diseases. The trans-fatty acid is an unsaturated fatty acid molecule. It occurs naturally in animal fats and is also produced in an industrial process. Trans fat produced in an industrial process has been banned by the FDA. It harms the human body in that it increases the bad cholesterol and lowers the good cholesterol. Cytokines are molecules that are produced typically by immune cells but are also produced by non-immune cells. Cytokines that are "good" help the body fight off and kill infections. But too many cytokines can be bad, like a big storm.[46] Proinflammatory cytokines are cytokines that are "bad" and make diseases worse.[47]

Rahmani et al. (2022) find that there is an optimal specific mid-range of IGF-1 that is associated with the lowest mortality (i.e., longest lifespan). Very high and very low levels of IGF-1 shorten the lifespan, i.e., there is an increase in mortality risk. Further, Rahmani et al. (2022) show that a high intake of milk-based products such as milk, cheese and yoghurt lead to high IGF-1 levels.

For those who are concerned about the adverse effects of milk and wish to consume plant-based milk, it is safe based on my experience. Do take the usual precautions such as not consuming after the expiry date, etc., and make sure the quality is good. I have been drinking soya bean milk for more than 20 years and I have also been consuming almond milk in recent years. I try to avoid preservatives and additives that are not natural. I feel fine. But it is good to ensure that all who are on a plant-based diet meet the daily requirements for the various nutrients.

7.2 About Eggs

Eggs contain essential nutrients such as proteins, potassium, choline, vitamin A, vitamin D, vitamin E, lutein and zeaxanthin, iodine, folate, phosphorous, selenium, etc.[48] [49] However, a whole egg contains about 200 mg of cholesterol and IGF-1. Cholesterol and IGF-1 in eggs are substances that have been the subject of research among nutritionists and medical professionals as to whether they are related to heart-related diseases and other illnesses. There are conflicting research findings on whether eggs are bad for a person's health.

Hu et al. (1999) find that an egg a day is unlikely to have any adverse effect on coronary heart disease (CHD) or stroke among healthy men and women.[50] However, Zhong et al. (2019) find that for the sample comprising US adults in their study, higher intakes of dietary cholesterol or eggs are associated with higher risks of cardiovascular diseases (CVD) and all-cause mortality.[51] CVD diseases are related to the heart and blood vessels and all-cause mortality refers to death from any cause.

Zhong et al. (2019) find these relationships to be statistically significant and that higher intakes of either cholesterol or eggs increase the risks. For every 300 milligrams (mg, 1 gram = 1,000 mg) increment of cholesterol intake, the risks of CVD and all-cause mortality increase by 17% and 18% respectively. For every additional consumption of half of an egg, the risks of CVD and all-cause mortality increase by 6% and 8% respectively.[52]

8. Does the Vegan Diet Help in Reducing the Risks of Future Pandemics?

Episodes of viruses that jumped from animals to humans have led to calls for more people to adopt the vegan diet. Animal to human transmissions of diseases include the 1997 bird flu outbreak in Hong Kong, the Severe Acute Respiratory Syndrome (SARS)-Coronavirus Disease (Covid) outbreak in 2002-2003, the 2014-2015 bird flu outbreak in the US, the current Covid-19 pandemic that has been raging globally since early 2020 (thought first discovered in late 2019) and the current bird flu outbreak in the USA that began possibly in Feb 2022. The reasoning put forward is that if we put no meat on the dinner plate, the chances of animal-to-human transmission will be very much reduced.

The bird flu outbreak in 1997 in Hong Kong led to the culling of about a million chickens.[53] The H5N1 virus that was responsible for the bird flu outbreak jumped from chickens to infect human beings. 18 people in Hong Kong contracted the virus and six people died.

The SARS-covid 1 outbreak in 2002-2003 highly likely has its origin in Guangdong province.[54] Researchers find that a significant proportion of food and animal handlers at markets in Guangdong had antibodies against this SARS-covid 1 virus. Tests conducted at the markets in Guangdong show that civet cats, ferret badgers, and a raccoon dog harbored the SARS-covid 1 virus. The results do not suggest that these animals play a significant role in the outbreak but it cannot be ruled that these animals were the source of the outbreak. The virus spread to 26 countries. The reported cases totaled 8096, and 774 persons died.

The 2014-2015 bird flu outbreak in the US saw more than 50 million chickens and turkeys who either died of the highly pathogenic avian influenza (HPAI) or were culled. 30 million poultry birds perished in Iowa alone.[55] Turkey farms affected were in the states of Arkansas, Iowa, Missouri, North Dakota, South Dakota, Wisconsin, and Minnesota, where the virus was initially identified. The chicken farms affected were in the states of Wisconsin, Iowa, Minnesota, North Dakota, Nebraska and South Dakota.

The Covid-19 virus was first detected in late 2019, and countries all over the world are still dealing with this pandemic. As of May 6, 2022, 513,955,910 cases attributed to the 2019 Covid-19 virus have been confirmed and 6,249,700 deaths have been reported to the World Health Organization (WHO).[56] However, WHO's own estimates of the number of deaths are higher if indirect deaths are included.

WHO estimates that, if including indirect deaths which refer to deaths related to Covid-19 but not directly attributed to Covid-19 complications, 14.9 million people died.[57] Indirect deaths refer to, e.g., people who died as they did not or could not seek treatment for other serious conditions owing to the

stress on the health care systems that have to deal with Covid-19, and patients not attended to owing to lockdowns. The source of the virus that led to the pandemic has not been clearly identified.[58]

The 2022 Highly Pathogenic Avian Influenza outbreak in the USA has presented a serious challenge to the states affected as these states are still dealing with the Covid-19 outbreak. The virus is highly contagious among chickens and turkeys and it was first discovered in Indiana in February 2022.[59] Better known as the bird flu, it has since spread to 34 states and killed 37 million chickens, as of May 6, 2022.[60] More poultry birds are expected to be culled. A case of a person who contracted the virus had been reported, as of late April 2022.[61]

The outbreaks described earlier are all very serious and have led to economic hardships for those affected. Covid-19 has resulted in the loss of many precious lives and led to very severe economic crises for many countries. Several countries had declared defaults on their debt obligations largely due to Covid. As of late May 2022, quite a number of countries have decided to live with the virus and have relaxed restrictions including allowing travelers from foreign countries without having to quarantine in an approved hotel or facility.

Many others are right in saying that even if all people turn vegan, animal-to-human transmission could still happen.[62] I agree. Humans interact with animals in many other ways and it is not just when animals are raised on farms.

Possible avenues for animal-to-human transmissions that are non-farming related include possible experiments on biological agents for warfare or protective purposes that involves pathogens, keeping pets, horse riding, horse racing, dog racing, pet shows, coming into contact with animals when in the wilderness, hiking, zoo visits, and wild animals intruding into homes. Transmissions from avenues that are non-farming related are certainly possible. Assuming no laboratories are doing experiments for biological warfare, I still firmly believe that the probability is reduced drastically if there is mass adoption of the vegan diet worldwide. Billions of farm animals are being kept in crowded conditions all over the world, making it much easier for pathogens to spread.

9. The Vegan diet is Good for the Environment

9.1 Global Warming: Basics

Mass adoption of a vegan diet globally will lower enormously the adverse impact brought upon by climate change. Global warming is a critical issue that is endangering the planet and future generations. Greenhouse gas emissions in the form of carbon dioxide, water vapor, methane, nitrous oxides, halons, and fluorinated gases contribute to global warming.

The world is still very much relying on fossil fuels for its energy needs. In 2020 (2019), about 83.1% (84%) of global energy consumption comes from fossil fuels.[63] [64] The proportions of the various energy sources are as follows: Oil makes up 31.2% (33%), natural gas accounts for 24.7% (24%), coal comprises 27.2% (27%), nuclear energy constitutes 4.3% (4%), hydroelectric power amounts to 6.9% (6%) and renewables provides the remaining 5.7% (5%) of the total energy consumed.

About 50 billion metric tonnes of carbon dioxide equivalents were emitted anthropogenically (i.e., attributed to human activities) in 2018.[65] Carbon dioxide equivalents are adjustments for the heating potency of other greenhouse gases (GHG) like methane and nitrous oxides in terms of tons of carbon dioxide. This adjustment involves a numerical figure known as the global warming potential (GWP) of a particular greenhouse gas.

Globally, livestock farming accounts for about 14.5% - 20% of all global anthropogenic greenhouse gases annually. The incremental emissions of greenhouse gases from animal farming are estimated by the Food and Agricultural Organization of the United Nations (FAO) to be about 14.5% of all anthropogenic greenhouse gases emitted. [66] Twine (2021) reports a higher figure and estimates that 16.5% of all greenhouse gases are attributed to animal farming.[67] Xu et al. (2021) also estimate a higher figure and estimate that animal farming contributes about 20% to the global anthropogenic greenhouse gases emitted.[68]

Based on circa 2010 data, Xu et al. (2021) estimate that globally, the entire system of food production causes 17.3 billion tons of anthropogenic greenhouse gases and that animal farming, including livestock feed, accounts for 57% of all food production emissions. It follows that about 0.57*17.3 or 9.86 tons of greenhouse gases are attributed to animal farming. The global greenhouse gas emissions for 2010 are estimated to be about 49 billion tons. This means that about 20% (i.e., 9.86/49) of all greenhouse gases come from animal farming. In this article, we will use a figure of about 14.5% to 20% to account for global anthropogenic greenhouse gases that are attributed to animal farming.

These are incremental estimates owing to livestock farming, i.e., if all people globally were to adopt the vegan diet, 14.5% to 20% of the global greenhouse gases will be removed from the atmosphere. The most important greenhouse gases from animal agriculture are methane and nitrous oxides in addition to carbon dioxide. Those who are on a vegan diet are contributing to our Earth in combating climate change from global warming.

Renewable energy sources, like solar power and wind power, are crucial to winning the battle against global warming. Mass adoption of the vegan diet also helps. Do not underestimate the small contributions at the individual level. A friend of mine joked that if he were to be on a vegan diet, that is hugely insignificant as a lot of people in the world are not vegans. It is indeed insignificant if only a few individuals take on a vegan diet. If everyone contributes a little, that is a lot on a global scale as we add up the contributions across billions of people all over Earth. We all can contribute to bringing about greater awareness.

Global temperatures, according to NASA, have already risen by about 1.10°C compared to the pre-industrial levels (1850 to 1900). We are seeing the consequences of global temperature rise currently. For example, the sea level has risen 8–9 inches since 1880.[69]

The central aim of the Paris agreement in 2015 is to limit global temperature rise to well below 2°C and ideally to 1.5°C above the levels during the pre-industrial period (1850 to 1900).[70] The IPCC now uses 1.5°C as the target instead of 2°C, i.e., the global temperature rise is limited to 1.5°C above the pre-industrial period.[71] With a target limiting temperature rise to 2°C the consequences of climate changes would be more severe than limiting temperature rise to 1.5°C. These consequences include higher sea-level rise, species extinction, greater frequency and severity of heat waves, droughts, and flooding, and greater declines in the yields of farm crops.[72]

More than 130 countries have committed or are considering achieving carbon neutrality by 2050. Carbon neutrality, according to the Intergovernmental Panel on Climate Change (IPCC), can be achieved if an entity that produces anthropogenic carbon dioxide (say 10 metric tons carbon) removes a similar amount of carbon dioxide (i.e., 10 metric tons) through, e.g., additional trees planting and technological advancements. Storing the carbon dioxide produced is also acceptable as meeting carbon neutrality.

To keep temperature rise below 1.5°C, GHG emissions in 2030 will have to be 55% lower than in 2018.[73] That means we need a significant reduction of 7.5% yearly in the amount of GHG every year. It

remains to be seen whether this reduction in GHG emissions can be reached. Mass adoption of the vegan diet can certainly contribute toward this target.

The IPCC in the summer of 2021 released modelling estimates on the total amount of additional global carbon dioxide emissions (CO_2) that Earth can have beginning in 2020 to keep the target of limiting temperature rise below 1.5°C. They estimate that to have a likelihood of 67% to achieve the target, Earth can tolerate additional total emissions of at most 400 gigatons of carbon dioxide.[74] This means that at the current carbon dioxide emission of about 40 gigatons annually, Earth only has ten more years. These estimates are for carbon dioxide only.

Modelling involves some errors and the estimates are based on various likelihoods. To achieve a higher likelihood of meeting the targets (i.e., to have more certainty), we will need a lower total amount of carbon dioxide emissions. For example, to have a likelihood of 83% of achieving the target, the total amount of carbon dioxide emissions is at most 300 gigatons. Based on 300 gigatons, Earth has a shorter period of about 7.5 years to achieve the target.

There is uncertainty about the amount of non-CO_2 greenhouse gas emissions. A higher (lower) amount of non-CO_2 greenhouse gases will lower (increase) the maximum amount of carbon dioxide emissions that can be tolerated to achieve the target. Hence at 67% likelihood, the maximum amount of additional carbon dioxide emissions will be lower than 400 gigatons.

Based on data for 2016 and in terms of carbon dioxide equivalents, carbon dioxide makes up about 74.4% of greenhouse gas, methane about 17.3%, nitrous oxide about 6.2%, and hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF6) make up the remaining 2.1%.[75]

National policies in all countries need to respond to this vital issue and look at their usage of fossil fuels (including natural gas, oil and coal). Governments across the globe need to adopt solar power, wind power and other renewable energy sources to manage the global temperature rise.

Limiting coal, oil and gas extractions will undoubtedly hit employment and the profitability of companies that are affected by this policy. Some governments, either at the local, state or national level have banned coal, oil and gas extraction in certain areas. These policies have economic and political consequences. While others have argued for a free-market approach to the extraction of coal, oil, and gas with no interference from the relevant governmental authorities, some others are concerned that the climate change problem is very serious and demand drastic government actions.

Many others hold the view that climate change is very serious but are advocating for a more measured approach on the extraction of fossil fuels. Jobs and economic growth are at stake when there are restrictions on the extraction of fossil fuels. The conflict between jobs in the fossil fuel industry and economic growth, and global warming is an issue that is not easy to manage as countries across the globe implement remedial measures to combat global warming. The fossil fuel industry is also related to energy independence and lesser reliance on foreign energy imports. The industry is intertwined with financial and national security.

9.2 Greenhouse Gases: Varying Potencies and the GWP

The GWP adjusts for the heating potency or rates of a particular greenhouse gas as compared to carbon dioxide over a certain time scale. [76] A '100-year (20-year) GWP' of a gas refers to the equivalent amount of carbon dioxide one has to release into the atmosphere to have the same effect on the Earth's temperature over 100 years (20 years). For example, methane is more potent than carbon dioxide in warming the atmosphere and carries a higher GWP. The warming potential of a GHG

can be measured over say 20 years, 100 years, or another time scale. But as carbon dioxide is the benchmark, carbon dioxide has a GWP of 1 regardless of whether we are considering the warming potential of a greenhouse gas over 20 years or 100 years.

Methane has a lifespan of 12 years when released into the atmosphere, after which methane is oxidized to water and carbon dioxide after a series of chemical reactions. So, the end-product of methane after its life span is water and carbon dioxide. Carbon dioxide can remain in the atmosphere for hundreds of years. GWP of methane over 20 years is higher than the GWP over 100 years. This is because methane has a short life span of 12 years and high warming potency and measuring the effects of warming over a 20-year period, methane shows a higher GWP than if measured over a 100-year time scale.

The Intergovernmental Panel on Climate Change (IPCC) has indicated a GWP for methane between 84-87 when considering its impact over a 20-year timeframe. It suggests a lower GWP figure of between 28-36 when considering its impact over a 100-year timeframe (GWP100) owing to a longer period for averaging the effects of methane. Methane traps heat at 100 times the rate of carbon dioxide immediately when released but its potency reduces over time and after 12 years, the end product of methane is water, and carbon dioxide which can still cause damage. For example, based on a 20-year GWP and using a GWP of 84-87, a metric ton of methane will translate to between (1*84) to (1*86) or 84 to 86 metric tons of carbon dioxide equivalents.

9.3 How Greenhouse Gas Traps Heat

As is well documented, carbon dioxide in the atmosphere along with water vapour serve their purpose in trapping heat, otherwise, Earth's temperature could be nearly zero Fahrenheit. The components of sunlight that hits the Earth, listed in the increasing order of the wavelength size are i) ultraviolet light (UV) with wavelengths shorter than 0.4 µm, ii) visible light, with wavelengths between 0.4 and 0.8 µm, and iii) infrared radiation with wavelengths longer than 0.8 µm (i.e., micrometre).[77]

Visible light and infrared radiation constitute about half of the radiation that hits the Earth's surface. UV light constitutes a minor but important portion of the radiation. UV light is important for the production of vitamin D. Together with infrared radiation, UV light is important for photosynthesis and plant growth.

The wavelength of the radiation that is emitted from Earth falls within the infrared spectrum whose wavelength ranges from 3 to 100 µm.[78] A greenhouse gas has the molecular structure to absorb infrared radiation emitted from the Earth's surface and re-radiating it back to Earth's surface. Heat re-radiated by a greenhouse gas radiates in all directions but the radiation toward the Earth's surface is of major concern.

The heat-trapping behavior property of carbon dioxide is related to its molecular structure. Carbon dioxide absorbs radiation with a wavelength of between 2,000 and 15,000 nm, i.e., 2 µm to 15 µm that is emitted from Earth.[79] The range of this wavelength falls between the infrared spectrum of 3 to 100 µm.

Oxygen and nitrogen, the other major atmospheric gases, absorbs energy within the wavelength of about 200 nm or less, i.e., 0.2 µm or less, which falls outside the wavelength range of the infrared radiation emitted from Earth. Hence, oxygen and nitrogen do not contribute to global warming.

During the daytime, Earth's surface and atmosphere absorb and radiate heat. Earth will be a much warmer place without heat radiating from Earth. During the nighttime, as the Earth cools, heat is also

emitted but the carbon dioxide and other greenhouse gases in the atmosphere trap some of the heat. This way, Earth is kept warm at night.

The problem arises when the Earth excessively absorbs more heat than it releases to space. This imbalance in the energy budget gives rise to global warming. The proportion of carbon dioxide during the pre-industrial revolution was about 278 parts per million (ppm) in the mid-1700s, and it exceeded 417 ppm in February and March 2021.[80]

An authoritative measurement of carbon dioxide in ppm that is used widely is from the National Oceanic and Atmospheric Administration (NOAA) Mauna Loa Laboratory. What NOAA used is a measure called the dry mole fraction. On the definition of ppm for carbon dioxide, suppose there are 1 million molecules in a parcel of air of which carbon dioxide is a constituent. The number of carbon dioxide molecules in that parcel of air is the ppm for carbon dioxide. Water vapor is excluded as a constituent in that air parcel.[81]

Another way of stating this is to measure the number of carbon dioxide molecules in a parcel of "dry air" (i.e., excluding water vapor) and divide this number by the total number of all molecules that constitute air in that air parcel. This result is the dry mole fraction. Suppose the result is "z". To get the figure in ppm, simply multiply "z" by 1 million. Other constituent gases of air include nitrogen, oxygen, methane and other gases, including inert gases.

The composition of water vapor in the air is extremely variable and is hence excluded from the measurement. The Mauna Loa Lab is located 3,400 m above sea level and is at a good altitude to measure the carbon dioxide in dry mole fraction. At that altitude, it is far away from vegetation or industrial activities and the measurements can be utilized to establish a baseline number for the mole fraction of carbon dioxide.

To get an approximate total weight of carbon dioxide in the atmosphere, we use the approximation that for each part per million by volume of CO2 in the atmosphere, the weight of carbon is equivalent to approximately 2.13 gigatons of carbon based on the figure provided by the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory.[82] The figure quoted is for carbon and to get the weight for carbon dioxide, we recognize that there are two atoms of oxygen and one carbon atom in the carbon dioxide compound molecule. The mass number of carbon is 12 and that of oxygen is 16. Hence, the mass number of carbon dioxide is 44 (i.e., 12+16+16).

Each element has a different atom. Carbon has a mass number of 12 as it has 6 protons and 6 neutrons (a total of 12). Oxygen has eight protons and eight neutrons (a total of 16). The weight or mass of an atom of an element is very much related to its mass number. The mass of the electron is very small and is about 1/1,836 that of the proton. We can ignore electrons in our calculations to obtain the weight of carbon dioxide. Assuming 417 ppm, the approximate weight of carbon dioxide in the atmosphere is then (44/12)*2.13*417, i.e., 3257 gigatons.

9.4 Carbon Sinks

We all love carbon sinks and wish to reduce man-made carbon sources. Carbon sinks absorb more carbon dioxide than they release. About 50% of the anthropogenic carbon dioxide emissions, i.e., from fossil fuel combustion, remain in the atmosphere, 25% is absorbed by land plants and trees, and the other 25% is absorbed into certain areas of the ocean.

Carbon dioxide is also emitted naturally from decaying vegetation, decomposing animal remains, volcano eruptions, respiration, etc. These natural emissions are naturally offset by carbon sinks,

including absorptions by oceans, photosynthesis both on land and ocean, etc. Carbon dioxide emissions attributed to human activities are the major contributors

Forests and oceans are the major carbon sinks. Between 2001 and 2019, the world's forests absorbed about 16 billion metric tonnes of carbon dioxide into the atmosphere each year and emitted about 8.1 billion metric tonnes of CO_2 per year.[83] Photosynthesis in the leaves absorbs carbon dioxide and releases oxygen. The carbon isolated, i.e., green carbon is used to build up the leaves, trunks, stems, branches, etc.

Plants also absorb oxygen day and night during respiration, but the amount of oxygen released from photosynthesis during the daytime is a lot more than the amount that plants take in during respiration in the daytime and night-time. Plants produce approximately ten times more oxygen during the day than what they take in during respiration at night. So, plants are an important source of oxygen for all humans.

Photosynthesis in the phytoplanktons and algae in ocean water is also helping to absorb carbon dioxide from the atmosphere. Blue carbon refers to the carbon stored in the oceans and photosynthesis is crucial for the formation of blue carbon.

9.5 Problems Faced by the Ocean as a Carbon Sink: Ocean Acidification

Carbon dioxide in the atmosphere interacts with ocean water and organisms found in the ocean. Interacting with ocean water, the carbon dioxide gas first dissolves into the ocean water. Once the carbon dioxide molecules dissolve, the dissolved carbon dioxide enters the ocean. The dissolved carbon dioxide now in its aqueous form may sink deep into the ocean or interacts with the ocean water to produce certain products. Hence, the dissolved carbon dioxide enters the ocean via i) the physical or solubility pump, ii) the biological pump and iii) the carbonate pump.[84]

i) The physical pump

When carbon dioxide in the atmosphere, CO_2 (gas), dissolves in ocean water, the dissolved carbon dioxide is usually denoted as CO_2 (aq), i.e., carbon dioxide aqueous. "aq" stands for aqueous. Some of the dissolved carbon dioxide may be released back into the atmosphere in a reversible reaction:

$$CO_2\,(gas) \leftrightarrow CO_2\,(aq) \qquad (1)$$

Ocean circulation further distributes the dissolved carbon dioxide from the surface, and some of the molecules sink deeper. It is easier for carbon dioxide to dissolve in colder waters than in warmer waters and the reaction in (1) shifts to the right in colder waters. Carbon dioxide dissolves more easily in the northern oceans and cold southern oceans than in the tropical waters. The dissolved carbon dioxide dissolves more easily in deeper ocean depths as it is colder. The pressure is also greater deeper into the ocean, and carbon dioxide is more soluble deeper into the ocean. Compared to the cold waters, smaller amounts of carbon dioxide diffuse into the sea waters in the warm tropical regions.

Warming ocean waters release more carbon dioxide into the atmosphere. Global warming leads to even greater warming of ocean waters.

The cold denser water sinks in a process called downwelling, which occurs mainly in very cold waters. The colder water is denser as it is colder and saltier as ice forms. The dissolved carbon dioxide is carried into the deep ocean and could stay there for hundreds of years before upwelling occurs. Wind

and the rotation of the Earth along its axis give rise to upwelling. As the Earth rotates along its axis, the wind tends to veer right in the northern atmosphere and veer left in the southern hemisphere.

As the wind blows the surface water away, the ocean water from below the surface rises to replace the water pushed away, creating the upwelling currents. When it happens in warm tropical waters, carbon dioxide can be released into the atmosphere. We know that warming a bottle of fizzy drink will release the gas in it.

ii) The biological pump

Phytoplanktons and algae in the ocean absorb either carbon dioxide from the atmosphere and/or dissolved carbon dioxide in seawater to produce oxygen in a process called photosynthesis. About 50%-80% of the oxygen in the atmosphere comes from phytoplankton and algae.

iii) Carbonate pump

As stated previously, carbon dioxide can be found in water as a dissolved gas. Some of the dissolved carbon dioxide reacts with ocean water to form carbonic acid, (2): [85] [86] [87]

CO_2 (dissolved) + $H_2O \leftrightarrow H_2CO_3$ (2)

Notes:
CO_2 is carbon dioxide.
H_2O is water.
H_2CO_3 is carbonic acid.

The reactions in (1) and (2) are reversible. Reversible chemical reactions are reactions in which the formed product of a reaction, which in this case in (2) is H_2CO_3, can revert to form the reactants, which are CO_2 (dissolved) and H_2O.

Carbonic acid is unstable by nature. The chemical reaction in which carbonic acid reacts with water molecules to form hydrogen ions and bicarbonate ions is as follows (3):

$H_2CO_3 \leftrightarrow H^+ + HCO_3^-$ (3)

Notes:
H^+ refers to a hydrogen ion.
HCO_3^- refers to bicarbonate.

The higher the concentration of hydrogen ions, the more acidic is the solution. Acidity or alkalinity is measured by pH (the Power of Hydrogen). pH below (above) 7 indicates acidity (alkalinity), and a pH of 7 is neutral. A higher pH reading means alkalinity has increased and a lower pH reading for a solution means its acidity has increased.

The formation of carbonic acid will result in ocean water becoming more acidic as it dissociates into hydrogen ions and bicarbonate ions. The reaction in (3) is reversible too. About the definition of ions, atoms that lose an electron (s) are positively charged and are called cations, and atoms that gain an electron (s) are negatively charged and are called anions. Opposite charges attract. Ions of opposite charges attract one another.

The bicarbonate ions may dissociate into carbonate ions and hydrogen ions:

$HCO_3^- \leftrightarrow H^+ + CO_3^-$ (4)

Note: CO_3^- is carbonate.

The reaction in (4) is also reversible. The carbonate ions, CO_3^-, from (4) react with calcium ions, Ca^{2+} to form calcium carbonate which is the building block of shells for aquatic animals with shells:

$Ca^{2+} + CO_3^- \leftrightarrow CaCO_3(aq)$ (5)

Calcium carbonate, $CaCO_3$, may also be formed this way:

$Ca^{2+}(aq) + 2\ HCO_3^-(aq) \leftrightarrow CaCO_3 + CO_2(aq) + H_2O$ (6)

The calcium ions react with bicarbonate ions to form calcium carbonate (which forms the shells) and carbon dioxide aqueous and water.

Carbon dioxide aqueous also reacts with carbonate ions and water to form bicarbonate ions.

$CO_2(aq) + CO_3^{2-}(aq) + H_2O \leftrightarrow 2\ HCO_3^-(aq)$ (7)

Carbon dioxide is also produced within the ocean itself from the respiration of ocean animals and aquatic plants, and the decay of aquatic animals and plants. From the above reactions, we see that carbon dioxide reacts with ocean water to form carbonic acid. Carbonic acid converts into bicarbonates and some bicarbonates convert into carbonates.

The total dissolved inorganic carbon (DIC) compounds in seawater comprise bicarbonate, carbonate and dissolved carbon dioxide. These carbon-containing compounds are inorganic as they are formed from non-biological origins and are not from living things like animals and plants. Carbon dioxide is inorganic.

Bicarbonate comprises about 90% of the DIC, followed by carbonate at about 9% and the remaining is dissolved carbon dioxide at 1% at the current pH of seawater which is about 8.1. Based on modelling, there will be a lower proportion of carbonates and a higher proportion of dissolved carbon dioxide as the ocean becomes more acidic. If the ocean becomes more acidic than pH of 8.1, there will be a higher proportion of bicarbonates up to a certain pH level and then the proportion of bicarbonates will decline subsequently with higher acidity.

In the presence of more anthropogenic carbon dioxide arising from more carbon emissions into the atmosphere, more carbon dioxide dissolves in ocean water, consistent with Le Chatelier's principle. Le Chatelier's principle states that when a change occurs in a system that is in equilibrium, the system will have a new equilibrium after the change is reduced, nullified or counteracted. For example, in (1), suppose one molecule of carbon dioxide gas is absorbed into the surface ocean water, another molecule of carbon dioxide is released into the atmosphere from the ocean water if the state is in equilibrium. If the proportion of carbon dioxide in the atmosphere increases, by Le Chatelier's principle, CO_2 (aq) increases. This means more carbon dioxide is dissolved in the ocean.

If reactants are increased, you get more products. When some of the carbon dioxide aqueous interacts with water in (2), carbonic acid is produced. As more carbonic acid is produced, we will see that the shift to the right in reaction (3) is favoured, i.e., more bicarbonate ions and hydrogen ions are produced. In the case of (3), the left-hand side of reaction (3) comprising H_2CO_3 (the carbonic acid) are

the reactants and the right-hand side comprising H^+ and HCO_3^- are the products. If H_2CO_3 is increased, more H^+ and HCO_3^- are produced, by Le Chatelier's principle.

Applying Le Chatelier's principle to (4), the ocean becoming more acidic from more hydrogen ions is the stress or new change to the equilibrium state. The reaction to the left in (4) is favored. Hence the system will reduce the hydrogen ions which contribute to the acidity of the ocean. As the hydrogen ions are reduced, the carbonate ions are reduced and more bicarbonate ions will result.

As stated previously, the carbon dioxide in aqueous form (i.e., the dissolved carbon dioxide) increases as the ocean absorbs more carbon dioxide. Le Chatelier's principle can be applied again to (6). As the dissolved carbon dioxide, $CO_2(aq)$, increases, we see the reaction to the left of (6) is favored and there is less calcium carbonate and more bicarbonate ions will result. Also, as $CO_2(aq)$ increases, the reaction to the right of (7) is favored - there are fewer carbonate ions, $CO_3^{2-}(aq)$, and more bicarbonate ions. With fewer carbonate ions and applying Le Chatelier's principle, the reaction to the left of (5) is favored resulting in lesser calcium carbonate. Calcium carbonate forms the shells of aquatic animals with shells and lesser calcium carbonate is a problem.

More emissions of carbon dioxide to the atmosphere result in the formation of more carbonic acid in seawater, and the formation of hydrogen ions and bicarbonates increases. The carbonate ions are needed for aquatic animals to grow their shells, and hence fewer carbonate ions are available for these creatures as more carbon dioxide dissolves in ocean water. This increased acidification leads to reduced carbonate ions. The reduction in carbonates is a major cause for concern.

Acidification can lead to less carbon dioxide being absorbed by the ocean, breathing difficulties for aquatic animals and the shells of certain aquatic animals being dissolved. The ocean has become more acidic since the pre-Industrial Revolution (or equivalently when the Industrial Revolution began). The pH during the pre-Industrial Revolution was 8.2 and it has since reduced to a current level of 8.1.[88] The ocean is currently alkaline but this reduction in pH means the ocean has become more acidic. Each reduction in a unit of pH means there is a 10-fold increase in acidity. Based on this scale, the ocean has become more acidic by about 25% when we compare the current pH reading to when the Industrial Revolution began.

The existing ability of the oceans to absorb carbon dioxide in the atmosphere does not mean the oceans can do this job indefinitely.[89] If global warming continues to deteriorate, the oceans will attract more freshwater from melting glaciers and ice sheets to the point that the surface waters would be very much less dense. If the surface waters are very much less dense than the waters deeper in the ocean, it would be harder for surface waters to mix with the waters in deeper oceans even with winds. This is akin to the less dense vegetable oil floating on top of freshwater – the two liquids do not mix well, leading to more stratification in the ocean waters.[90]

The stratification in the ocean waters has become worse with global warming. Li et al. (2020) find that stratification globally has increased by a substantial 5.3% over the period 1960–2018.[91] When the oceans stop circulating, the surfaces of the ocean waters cannot continue to absorb carbon dioxide as they become saturated with the gas.

9.6 Problems Faced by the Ocean as a Carbon Sink: Overfishing

Overfishing and mismanagement of marine ecosystems are a challenge for our oceans to function as effective carbon sinks. Global human consumption of seafood is about 156 million tonnes yearly from an estimated total production of about 179 million tonnes (2018 data).[92]

A fish stock refers to the mass of fish in a particular location, and a more detailed analysis could include the number of fish, varying sizes of the fish, fish species, and the age profiles of the fish mass. An overfished stock refers to the population of fish in a particular locality that is below the biomass (i.e., the amount of fish, or *B*) that produces the maximum sustainable yield (MSY), B_{MSY}. The MSY is the theoretical maximum fish harvest that can be sustained in the long term. If too many fish are harvested, the low biomass remaining will not be enough to repopulate in the future to the extent it could reach B_{MSY}, and this scenario fits the definition of an overfished stock.

Certain places have experienced losses owing to overfishing or warming of the ocean or both. The Food and Agricultural Organization and other organizations have voiced out about the unsustainable trajectory of overfished stocks in our oceans. The FAO estimates that the percentage of fish stocks globally that are within biologically sustainable levels has dropped from 90% in 1990 to about 66% in 2017. For example, the Mediterranean and the Black Sea region are the world's most overfished sea locality. Fishing stocks in the Mediterranean Sea and the Black Sea are at very unsustainable levels.

Fishing businesses contribute to greenhouse gas emissions[93]:

- Damage to natural carbon sinks: Some fishing equipment may damage the seabed and carbon habitats like seagrass meadows and muddy sediments. Seagrass meadows are important carbon sinks. Seagrass takes in carbon dioxide from water for photosynthesis, absorbs carbon up to 35 times faster than tropical rainforests, and sequesters 10% of the ocean's carbon each year.[94]

- Marine ecosystem destabilized: Overfishing can lead to imbalances in the ocean ecosystem. [95] Also, overfishing of predator fish like sharks and bigger size predator fish can lead to an increase in the ocean's carbon dioxide production. The killing of whales, our marine mammal relatives, takes out a part of the ocean's ability to store carbon. Whales that are alive feed the phytoplanktons with their excrements. Oceans contribute about 50% of the Earth's oxygen. Phytoplanktons play a large role in producing oxygen through photosynthesis.

  Coming back to predator fish, when the typically bigger predator fish eat the smaller fish, the bigger fish has a net gain of about 10 percent of the total calories available in the smaller fish. The predator has to burn energy to look for food, swim, generate heat, carry out its own metabolic processes, etc. For humans, we exercise, talk, walk, think, produce heat, and carry out our metabolic processes. This is commonly known as the 10 percent rule in elementary biology classes. The figure of 10% is approximate and varies depending on the types and species of animals and fish. When there are not that many bigger fish remaining to eat the small fish, the small fish population will grow bigger, and more carbon dioxide is produced than if the predator fish were available.

  Human fishing activities target the larger predator fish. The population of large predator fish is estimated to be at about 10% of the pre-industrial level by 2003. Many are at risk of extinction. In some sense, humans have become the predator of the large predator fish through fishing activities.

- Fossil fuel combustion from fishing vessels: Greer et al. (2019) estimate that 207 million tonnes of carbon dioxide were released into the atmosphere by marine fishing vessels in 2016. This is equivalent to 51 coal-fired power plants. Quite a number of the fishing vessels are quite old.[96]

An important takeaway is that it is best for humans not to consume aquatic animals. Let the marine ecosystem find its own balance. The marine ecosystem can function by itself without human intervention.

9.7 Animal Agriculture and Greenhouse Gas Emissions

Animal agriculture uses fossil fuels for electricity on farms, transportation, and for producing the grains that are fed to the farm animals. Crop farming uses fossil fuels to generate the power needed for tillage, transportation, grain drying, fertilizer manufacture, manufacturing pesticides, manufacturing and operation of equipment, etc. A significant proportion of the crop products is for producing animal feed. With fossil fuel combustion, there is no escape from the release of climate-changing carbon dioxide as a by-product and pollutants like carbon monoxide, sulphur dioxide, etc.

Focusing on the usage of fossil fuel energy for animal agriculture, Pimentel (1997) estimates that one kilocalorie (kcal) of animal protein on average requires approximately 28 kcal of fossil fuel energy.[97] [98] In comparison, 1 kcal of plant protein requires an input of 2.2 kcal of fossil energy.[99] The amount of energy required to produce one kcal of meat protein is about 11 times that of the energy required for producing a kcal of plant protein.

For beef and pork, the ratios are much higher – it takes about 40 calories of fossil fuel energy to obtain 1 calorie from beef (40:1). For pork, the ratio is about 14:1. In contrast, it takes 2.2 calories of fossil fuel to obtain 1 calorie from corn (2.2:1).[100] [101]

There are billions of farm animals out there on any given day. The more farm animals there are out there, the more fossil fuels are needed to raise them. Growing crops to feed this large number of farm animals needs fertilizers and fertilizers come from fossil fuels.

The population of chickens globally was estimated to be 33 billion (2020 estimate).[102] Consider this as a figure for reference as it is difficult to estimate the number of chickens worldwide owing to their short time on Earth before they are slaughtered and the uncertainty about the number of chickens reared in remote places. However, the number of chickens today would still be a lot even if the figure was overestimated by 5 billion to 10 billion. In 2022, the number of cattle globally was estimated at 1 billion,[103] and the number of pigs at about 780 million.[104]

9.8 Global Food Supply Can Increase by 49% with Plant-Based Diet

Foley et al. (2011) estimate that the global food supply for humans could increase by 49% in terms of calories delivered if the world population switches to a plant-based diet. [105] This does not require an expansion of croplands, i.e., this increase can be achieved on existing lands that are used to grow crops.

This is significant as many people are still struggling to find food. With more plant-based foods added to the global food supply, the prices of foods will become more affordable as there is more supply available for human consumption. That would reduce hunger and poverty. As more people are fed, they can work more to earn income to get themselves out of poverty.

The increase in food supply for human consumption if all people turn vegan comes as no surprise as quite a lot of farm crops are grown to feed livestock. For example, more than 90% of U.S. soybean goes to feed livestock and poultry.[106] More than 60 percent of the world's corn and barley are fed to farm animals.[107]

Cassidy et al. (2013)[108] estimate that 55% of the crop calories are directly consumed by humans, another 36% is consumed by livestock, and the remaining 9% goes toward biofuels and other industrial uses. US agriculture could feed an additional 1 billion people by shifting crop calories exclusively for human consumption. Existing croplands can feed an additional 4 billion people if all crops are grown for human consumption. If people eat less meat, the increased food supply can be used to feed malnourished children, potentially millions more.

Livestock farming is generally an inefficient means to produce food for human consumption. For every 100 calories of appropriate feed that is fed to cattle, pigs, chicken, hens (for eggs), cows (for milk), the calories received back by humans ultimately are 3 calories for beef, 10 calories for pork, 12 calories for chicken meat, 22 calories for eggs, and 40 calories for milk respectively.[109] Energy is lost in the process of raising animals for consumption by the next trophic level, which in this case is the human race. Animals have to be fed to go about their daily activities like walking, eating, breathing, keeping warm, etc. All these activities require energy input.

It takes some period of rearing and feeding before farm animals like cattle, pigs and chickens are slaughtered for meat. For cattle, it takes about three years. For pigs, it is about 6 months (suckling pigs are slaughtered at about 6 weeks). For chickens, it is between 7 weeks to 1 ½ years. Raising them for these periods requires livestock feed. Also, body parts like certain organs, bones of animals, fats, cartilage, and head are not fit for human consumption.

Comparing the periods of rearing before these farm animals are slaughtered, their natural lifespans are much longer. The natural lifespan of cattle is 18 to 22 years. The natural lifespan of a pig is 15 to 20 years and that of a chicken is 3 to 7 years.

It is worth noting that a pound of meat and a pound of plant-based foods such as legumes, seeds, and grains are almost on par on average in terms of delivering proteins for human consumption.[110] Some plants pack more proteins than animal proteins pound for pound. For example, about 36 grams of proteins can be found in 100 grams of raw soya beans.[111] In comparison, 100 grams of beef contains about 20 grams of protein.[112]

Depending on the type of beef, cooked or raw, estimates on the amount of protein in 100 grams of beef vary. Cooked beef contains more proteins in 100 grams as cooking reduces the water content, making it denser in nutrients. Estimates of protein in raw red muscle beef range from about 25 to 25 grams.[113] Cooked beef contains about 36 grams.[114] 80% lean meat/20% fat, raw ground beef contains 17.2 grams of proteins.[115] 100 grams of cheddar cheese contains about 25 grams of proteins.[116]

Plant-based foods in addition provide fiber, sterols and stanols. Plant sterols and stanols help to reduce the “bad” LDL cholesterol levels without affecting the levels of HDL cholesterol.

9.9 Significant Water Savings and Much Reduced Water Pollution with Vegan Diet

Water usage for animal agriculture has raised alarms as livestock farming uses a lot more water, and water is a scarce resource in many parts of the world. To get a better understanding of water usage for animal agriculture and human consumption, the sources of water can be categorized into three types: green, blue and grey water. Green and blue water are from natural sources while grey water is from human sources.

Green water is water in the soil that plants and microorganisms in the soil have access to for their water needs and growth. Blue water sources include the water that we see in streams, wetlands, rivers, lakes and reservoirs. Sources of blue water include glaciers, aquifers and snowpack. Blue water

can be used for drinking and irrigation. Rainwater replenishes green water and blue water. Blue water replenishes green water, when necessary.

Grey water refers to water from domestic activities like laundry, washing food items and kitchen utensils and showers. Uses of recycled grey water include irrigation, toilet flushing and general washing.

If the food for the cattle is in the form of pasture grass, green water usage is significant. If cattle are fed grains as in industrial livestock production, the blue water usage or footprint is high.

More water is used to produce animal proteins as compared to plant proteins. For example, an estimate of the amount of water required to produce a pound of beef is about 1,800 gallons of water.[117]

A pound of tofu requires only an estimated 302 gallons of water to produce while a pound of unprocessed oats requires about 290 gallons.[118]

Jalava et al. (2014) estimate that water consumption in the world can be reduced by as much as 21% if all people go on a vegan diet.[119] Freshwater is a scarce resource in many parts of the world and this is a significant saving.

Pollution of freshwater arising from animal agriculture, mainly from animal manure, is another very serious problem. The amount of animal manure from farm animals far exceeds human manure by as much as 3- to 20-fold in the USA.[120] Human manure is usually treated in most developed countries, but not animal manure.

9.10 Animal Agriculture and Land Use

The Earth's surface is made up of 29% land (149 million km^2) and the remaining 71% is ocean or sea water (361 million km^2). The Earth's total surface area is about 510 million km^2. 71% of the land surface is habitable (104 million km^2), 10% comprises glaciers and the remaining 19% is barren land which includes rocks, deserts, beaches, and dunes. Focusing on the area for habitable land, about 50% (about 51 million km^2) is used for agriculture, about 37% comprises forests (39 million km^2), about 11% comprises shrubs (12 million km^2), about 1% is used for urban and built-up area, and 1% comprises sources of freshwater, e.g., lakes and rivers.[121]

The land area (40 million km^2) that is covered by 77% of total agricultural land comprises pasture land for grazing (60% or 30 million km^2), and land used to grow crops for livestock feed (10 million km^2). The remaining 23% (11 million km^2) is used to grow crops specifically for human consumption.

It is worthwhile to note that based on estimates by Poore and Nemecek (2018)[122] that the 40 million km^2 of land that is used for livestock farming supplies only 18% (37%) of the world's calories (proteins) for human consumption and the other 82% (63%) of calories (proteins) comes from the 11 million km^2 of land used to grow crops specifically for humans.

About 60 percent of the world's agricultural land is grazing land.[123] Much of grazing land cannot be converted to growing crops owing to the nature of the soil on grazing land. Mottet et al. (2017) estimate that globally, out of the 2 billion hectares of grassland that livestock is using for grazing, about 700 million hectares (close to 35% or one-third) could be converted into cropland.[124] This means that about 65% of grassland cannot be used for growing crops. About 65% or close to two-thirds of the UK's farmland is best suited for growing grass than other crops.[125]

It looks like there is a strong reason for raising cattle and sheep on grazing land as most of this land cannot be used for growing crops. The argument is that humans will be able to obtain animal proteins and calories from cattle and sheep that are grown on grazing land that would otherwise go to waste. The grass that cattle feed on is not suitable for human consumption anyway.

Cattle raised on pasture land feed on pasture grass for most of their lives and are fed supplemental grains when necessary. They are also fed certain quantities of various grains at certain ages and weights so that they could gain a certain target weight faster before they are slaughtered. The argument that cattle and sheep convert calories from feeding on food items unsuitable for humans into meat and milk for humans is valid. The food items unsuitable for humans include grass on pastures, corn stalks, wheat straw and byproducts such as distiller's grains (i.e., leftovers after the beer is brewed). While it is true that livestock is generally inefficient in converting calories for human consumption, the inefficiency of converting calories to beef for cattle that feed on the grass on pasture land, corn stalks, wheat straw and certain byproducts is not as high as these items are not suitable for human consumption anyway. However, other issues need to be looked at, to be discussed next.

Consumption of meat results in a higher likelihood of contracting several chronic diseases including certain cancers, diabetes and heart-related diseases. Pollution of freshwater due to animal manure is a serious issue. For pasture lands that are not properly managed, overgrazing may lead to drought, excessive soil erosion, loss of pasture, herbs and rootstocks, desertification and possibly starvation for the community. Many on a plant-based diet are concerned about the slaughtering of animals. Cattle are also being fed grains which can be used to feed humans.

Greenhouse emissions such as methane from cattle and sheep contribute to climate change. Methane is more potent than carbon dioxide as a greenhouse gas. A Western cow produces about 120 kg of methane per year, mostly from belching. A small percentage of the methane produced by cattle is from flatulence. A non-Western cow produces about 60 kg of methane per year. A sheep produces about 8 kg of methane per year, while a human being produces about 0.12 kg of methane per year from flatulence.[126]

If the demand for beef, lamb, and dairy were to decline, owners of cattle farms will have to adjust and look for other uses for their land. Hopefully, there will be better technologies in place to convert more grazing land for crop production to feed a growing world population. More efforts are needed to encourage people to look at the benefits of a vegan diet. The current trend does not seem to indicate that the demand for beef, other animal meats and dairy is on a downward trajectory.

9.11 Permafrost, Glaciers, Sea Level Rise

Greenhouse gas emissions from animal agriculture currently amount to about 14.5% to 20% of the total emissions. If humans could cut down on meat, that is a big step toward fighting global warming. Widespread adoption of a plant-based diet helps to mitigate the thawing of permafrost, melting of glaciers, and warming of seawater.

Permafrost refers to the ground that remains frozen for at least two consecutive years. It is essentially a mixture of organic materials, soil, rock and sediments usually bound together by ice.[127] Glaciers are accumulated ice masses on surface land, formed from snow over many years. Most glaciers today can be traced to the Ice Age.[128] Some glaciers took hundreds of years to form and some are a couple of hundred years in age. There are some which were formed over thousands of years. The Crater Glacier (also known as Tulutson Glacier) in Mt St Helens, Washington state, is a growing young glacier that

was formed about 25 years ago. While many glaciers are receding, the Crater Glacier is atypical as it is still growing owing to certain structural features of the formation that draw and keep snow, and snowfall in the area.[129]

Significantly large areas of permafrost can be found in Russia and Canada near and above the Arctic circle. The melting of permafrost can lead to more damage to the environment as methane that is trapped below the permafrost will be released.

The annual global emission of methane is about 570 million metric tons. About 40% is from natural sources and the remaining 60% is from man-made activities.[130] About a third of man-caused methane emission comes from livestock.[131] If measures are not taken to control the thawing of permafrost, more methane will be emitted. That will be a disaster. About 40% of the world's permafrost could disappear by 2100 if the world does not take this seriously.[132]

Methane averaged about 0.00018957 percent or 1895.7 parts per billion (ppb) of air in 2021. It might look like a small figure but about one-sixth of the last few decades' global warming is attributed to methane.[133] The increase in the concentration of atmospheric methane in recent years has given rise to concern. The increase in 2021 of 17 ppb is greater than the increase of 15.3 ppb in 2020.

Methane emissions from the Arctic have been increasing. Knoblauch et al. (2018)[134] reveal that permafrost soils from the Northern pole would generate one gigaton or 1000 million tons of methane by 2100. With temperatures warming, the frozen organic matter will decay owing to thawing. If oxygen is available, this decaying process will produce carbon dioxide and if oxygen is not available, methane will be released.

Thawing rock formations in permafrost also releases methane, a constituent of methane hydrate that is found underneath and within the permafrost. Methane hydrate is a crystalline solid containing methane trapped by frozen water. In 2020, the Siberian heat wave led to a surge in methane emissions in the Arctic permafrost. The temperature increased by an average of 10.8^0F above 1979-2000 norms. Studies have shown that temperature has risen by about 0.3^0C in the permafrost around the Arctic and Antarctic between 2007 and 2016.[135]

Melting glaciers is a serious issue. If all of the glaciers on Earth were to melt, the sea level will rise by about 70 m or 230 feet. That will flood the coastal areas and cities. Glaciers have been melting at an alarming rate over the past few years. 227 gigatonnes of glacier ice were lost annually from 2000 to 2004, but the loss accelerated to an average of 298 gigatonnes each year after 2015. The melting glacier that flows into the sea from the land surface will cause the sea level to rise.

The global sea level has been rising. Sea level rose on average about 3.6 mm per year from 2006-2015. The global mean sea level is currently about 8–9 inches (21–24 centimeters) above the level in 1880. The sea-level rise has been accelerating in recent decades. A third of this increase in sea level has been coming in over the past two and a half decades.[136] The rising sea level is mostly due to water from melting glaciers and ice sheets, and the thermal expansion of warming seawater. Water from glaciers that melted accounts for about 21% of the sea level rise over the past two decades.[137]

Icebergs that melted also contribute to sea level rise but the contribution is small. We know that ice that melts in pure water will not result in any changes to the water level. However, an iceberg is of a different density than salty seawater. Icebergs are made of fresh (non-salty) water. Sea water is salty, and denser as compared to the iceberg. When an iceberg melts, the volume of water increases by about 2.6% more than the volume of water that the iceberg has displaced. Sea level increase per year due to melting icebergs is about 49 micrometers. [138] (1 m = 1,000 mm, and 1 mm = 1,000

micrometers). Compared with about 3,600 micrometers (3.6 mm) of sea level rise per year, this is not big but worth monitoring.

Global warming has led to the thawing of permafrost, melting glaciers, and warming of sea water. The vegan diet can help to bring down some of the annual greenhouse gas emissions that contribute to global warming.

10. Fertilizers, Animal Wastes, and the Story Behind Nitrous Oxide

Fertilizers feed the world. Fertilizers can be in organic form or inorganic form. The organic fertilizers are plant-based or animal-based, examples of which include compost, animal manure and leaves. The inorganic fertilizers are from chemical processes and the most commonly used fertilizers contain the elements nitrogen, phosphorous, and potassium.

The element nitrogen is essential for protein formation. Phosphorous is for photosynthesis, and for storing and transporting nutrients. Potassium is essential for plant growth, photosynthesis, and strengthening a plant's ability to deal with dry weather and confront diseases. Nitrogen-containing fertilizers include ammonia, urea, ammonium nitrate and ammonium sulphate. Without the production of nitrogen fertilizers, Smil (2004) estimate that crop production would be half of today's levels.[139]

The higher outputs for various types of crops enabled by nitrogen fertilizers account for feeding about 50% of the population today. These crops include those that are used as livestock feed for farm animals which provide meat and milk (from cows) for human consumption. Without nitrogen fertilizers, the world population would be about half of today's level.

The nitrogen fertilizers supply the nitrogen element that is essential to produce proteins in plants. Plants require glucose and proteins for growth and reproduction. Glucose is made up of the elements H, C, and O. In addition to the elements H, C and O which are necessary for glucose formation, the elements to form proteins in plant cells are nitrogen (N) and sometimes, sulphur (S). Sulphur is an essential element for plant growth and photosynthesis.

Water is absorbed by plants via the roots. The carbon dioxide that plants absorb during photosynthesis reacts with water to form glucose during photosynthesis. During photosynthesis, oxygen is released into the atmosphere.

To form glucose, plants obtain hydrogen from water during photosynthesis and carbon from the carbon dioxide that is absorbed during photosynthesis. The oxygen in glucose comes from carbon dioxide. The oxygen that is released into the atmosphere comes from water.[140]

Plants can absorb sulphur from the atmosphere but most of the sulphur for protein formation comes from the absorption of sulphate ions via the roots. The element that is discussed next for protein production is nitrogen.

Nitrogen makes up 78% of the air in the atmosphere. However, plants cannot extract nitrogen from the air. For their nitrogen needs, plants can absorb nitrogen-containing ions in the form of nitrates (NO_3^-) and ammonium ions (NH_4^+) from soils. The nitrates and ammonium ions are formed in the nitrogen cycle. The nitrogen cycle is a series of processes that convert nitrogen gas in the atmosphere

and other nitrogen-containing compounds such as fertilizers to a form of nitrogen that is usable by plants and other living organisms. In the final stage of the nitrogen cycle, nitrogen gas is released into the atmosphere or soils through another set of processes.

Plants can get nitrogen through lightning strikes. When lightning strikes, the tremendous energy released breaks the strong bond between the nitrogen atoms in the nitrogen gas. The nitrogen atoms can then react with oxygen to form nitric oxide (NO):
$N_2 + O_2 \rightarrow 2NO$

The nitric oxide reacts with oxygen further to form nitrogen dioxide (NO_2):
$2NO + O_2 \rightarrow 2NO_2$

Nitrogen dioxide reacts with water to form nitric acid (HNO_3):
$2NO_2 + H_2O \rightarrow 2HNO_3$

Nitric acid reacts with, e.g., calcium oxide that is found in soils to form calcium nitrates.
$CaO + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O$

Calcium nitrates formed in the soils dissolve quickly in water to form calcium ions and nitrates ions.
$Ca(NO_3)_2 + H_2O \rightarrow Ca^{2+}(aq) + 2NO_3^-(aq)$

The nitrate ions (NO_3^-) are absorbed by the plants.

Plants can also get the nitrogen after being fixed in the soil by nitrogen-fixing in a natural process, or from nitrogen fertilizers but after undergoing certain chemical reactions. The nitrogen-fixing cyanobacteria convert the nitrogen from the air into ammonia (NH_3).[141] The simplified form of the equation is as follows:

$N_2 + 3H_2 \rightarrow 2NH_3$

Nitrogen fixing is about converting the nitrogen gas into a nitrogen-containing compound like ammonia. The process that follows next is called nitrification. Nitrification is a process involving nitrifying bacteria using oxygen to convert nitrogen-containing compounds to nitrates. The ammonia-oxidizing bacteria then convert the ammonia to nitrites ions (NO_2^-) through an oxidation process.[142]The nitrite ions are then converted into nitrate ions (NO_3^-) by another type of bacteria, the nitrite-oxidizing bacteria. The steps of nitrification are as follows:

Ammonia → Nitrites → Nitrates

Nitrates are then absorbed through the roots of plants. Plants can convert the glucose formed from photosynthesis and the nitrates absorbed to produce amino acids.[143] Amino acids join to form proteins, i.e., proteins are made up of amino acids. We have to thank the nitrogen-fixing bacteria in the soils that have been helping mankind all these years.

The carbon, oxygen and hydrogen elements in plant cells are produced during photosynthesis. The availability of nitrogen in the form of nitrates in soils often limits the growth of plants. Compared with carbon, oxygen and hydrogen, nitrogen is scarce as they are found in nitrates in soils naturally. With a given area of land to produce crops, nitrogen fertilisers applied to soils can increase yields in areas

that are nitrogen deficient. So, the scarcity of nitrates in certain farm areas necessitates the application of nitrogen fertilizers.

A major nitrogen fertilizer that is used all over the world is ammonia with the chemical formula NH_3. The nitrogen for ammonia is harvested from the atmosphere through a chemical process developed by Fritz Haber. Haber did it in a small tube after many years of research.[144]

Haber's work was an earth-shattering discovery. The fruits of his research work are a breakthrough of tremendous consequence as the source for nitrogen gas is readily available in the atmosphere but nitrogen is a highly unreactive inert gas owing to the strong bonding between the two atoms. Hence the process requires high temperature and pressure to break the strong bonding between the two nitrogen atoms in the molecule of nitrogen gas. Breaking this bond enables the nitrogen atoms to react with hydrogen atoms to form ammonia. Without breaking the bond between the nitrogen atoms in the nitrogen gas, the nitrogen atoms cannot react with the atoms of other elements such as the hydrogen atoms. Carl Bosch further developed the engineering process to produce ammonia on a larger scale.

Hydrogen is obtained from the chemical reaction involving methane and water. The source of methane comes from natural gas. Methane, a potent greenhouse gas, makes up about 70-90 percent of natural gas. During this chemical reaction, hydrogen and carbon dioxide are produced:
$CH_4 + H_2O \longrightarrow 3H_2 + CO$.

CH_4: methane
H_2O: water
H_2: hydrogen gas
CO: carbon monoxide

Additional hydrogen is generated in the second stage:
$CO + H_2O \longrightarrow H_2 + CO_2$.

The nitrogen and hydrogen then react in the Haber-Bosch process to produce anhydrous ammonia, NH_3 :
$3H_2 + N_2 \rightleftharpoons 2NH_3$

"Anhydrous" means without water. The whole engineering process for industrial production is known as the Haber-Bosch process.

Anhydrous ammonia is converted into liquid form for use as a fertilizer. When the ammonia in liquid form is injected into the soil, the ammonia reacts with water to form the ammonium ions, NH_4^+ (i.e., $NH_3 + H_20 \leftrightarrow NH_4^+ + OH^-$). The ammonium ions are absorbed by plants for their nitrogen needs. Ammonium ions are an ingredient to form glutamate, an amino acid. In certain soil conditions, nitrifying bacteria in the soils can also convert the ammonium ions into nitrates in the process called nitrification. As stated earlier, the two types of nitrifying bacteria are ammonia-oxidizing bacteria and nitrite-oxidizing bacteria. The ammonium ions are then converted to nitrites by ammonia-oxidizing bacteria. The nitrites formed are then converted to nitrates by nitrite-oxidizing bacteria. Nitrification occurs in well-aerated and well-drained soils. The nitrates are then absorbed by plants.

The Haber-Bosch process is an extremely important breakthrough that has led to the production of nitrogen fertilizers at an economical cost. The application of fertilizers enables a much more plentiful harvest of crops annually given that nitrates in the soils are limited. The higher yield from croplands has led to a higher population on Earth. For example, in 2015, the world population stood at 7.38 billion. It is estimated that the availability of fertilizers enabled 3.54 billion to be fed, which is about half of the world's population.[145]

Before the Haber-Bosch process, natural fertilizers were grossly insufficient for a growing population. It was clear to many that the Haber-Bosch process was a revolutionising invention and the Nobel Committee recognized that. Though Haber was awarded the Nobel Prize in 1918, many disagreed with his Nobel Prize award given his involvement in chemical warfare to aid Germany during World War I.[146]

To produce fertilizers such as ammonium nitrate fertilizer, ammonia is engineered to react with nitric acid, HNO_3, to produce ammonium nitrate, NH_4NO_3. Ammonium nitrate can also be used as an explosive. Ammonium nitrate is highly soluble in water. When applied to soils, ammonium nitrate simply dissociates in water into ammonium ions, NH_4^+ and nitrate ions, NO_3^-. These ions are then absorbed by the plant roots for nitrogen.

The downsides to using fertilizers include a significant amount of carbon dioxide emissions from the process of producing nitrogen fertilizers, nitrous oxide (N_2O) emissions from the application of fertilizers into the soil, pollution of fresh water from excessive nitrates, atmospheric pollution from ammonia, and eutrophication.

The Haber-Bosch process to manufacture the ammonia fertilizer under high pressure and temperature requires a large input of energy.[147] The large input of energy comes from using lots of fossil fuels and the process consumes about 1.8% of the world's total energy production in 2018.[148] Proportionately, one would expect that the anthropogenic carbon dioxide emissions emitted from the Haber-Bosch process would be close to the figure of 1.8% of the energy used. It does. The process accounts for about 1.8% of global anthropogenic carbon dioxide emissions or about 500 million tons of carbon dioxide equivalent. Worldwide, about 96% of the hydrogen that is extracted uses fossil fuels. 90% of the ammonia produced utilizes fossil fuels.[149]

The increasing trend in the use of nitrogen fertilizers since the mid-20th century is not showing any sign of decline. Along with this increasing trend, the emissions of nitrous oxide have also increased. Nitrous oxide constitutes about 6.2% of the total global greenhouse emissions in terms of carbon dioxide equivalents. It is about 300 times more potent than carbon dioxide as a greenhouse gas and it eats up the ozone layer.

Natural sources of nitrous oxide account for about 62% of total emissions and anthropogenic sources account for the remaining 38%. Natural sources include soils under natural vegetation, oceans, and atmospheric oxidation of ammonia. Human-caused sources include agriculture, fossil fuel combustion, biomass burning and atmospheric deposition.

Farming accounts for about two-thirds of the global human-caused nitrous oxide emissions. The increase in nitrous oxide emissions is showing an increasing trend. Nitrous oxide emissions from agriculture come about as a result of excessive applications of synthetic fertilizers, and animal urine

and manure. Finding the right balance in the applications of fertilizers is crucial to reducing nitrous oxide emissions.

When there are excessive nitrates in the soils from the overuse of ammonia fertilizers, plants are not absorbing these excess nitrates. As stated earlier, ammonia is converted to ammonium ions in the presence of water. The ammonium ions are then converted to nitrites by ammonia-oxidizing bacteria. The nitrites formed are then converted to nitrates by nitrite-oxidizing bacteria.

In areas with oxygen shortage, usually in damp or water-logged soils from rainfall, denitrifying bacteria can convert the nitrates into nitrites. Denitrifying bacteria can survive in both situations when oxygen is available or unavailable in the soils. These bacteria get the oxygen from the breakdown of nitrates to support respiration. Although the end product is nitrogen gas, other end products from different stages of the reactions are possible depending on the environmental conditions such as soil pH. The possible end products include nitrite, nitric oxide, nitrous oxide, and nitrogen gas (N_2):[150]

Nitrate (NO_3^-) → Nitrite (NO_2^-) → Nitric Oxide (NO) → Nitrous oxide (N_2O) → Nitrogen gas (N_2)

It makes sense not to apply nitrogen fertilizers when it rains or when the soils are clogged with water. When there are excessive nitrates, plants are not taking up these nitrates as they have enough. The denitrifying bacteria come into play as described above in different stages of the reactions aided by specific enzymes found in these bacteria. The nitrates may be converted to nitrites in the presence of the specific enzyme, nitrate reductase. The nitrites may be converted to nitric oxide (NO) aided by another enzyme, nitrite reductase.[151] The enzyme, nitric oxide reductase, aids in the conversion of nitric oxide to nitrous oxide for this stage to happen. The enzyme, nitrous oxide reductase converts the nitrous oxide to nitrogen gas, the final step.

For nitrous oxide to be produced, nitrates are needed which means that the amounts of fertilizers play a part. While nitrogen gas which is the end product of denitrification may be formed, nitrous oxide or nitric oxide (NO) may be released into the atmosphere under certain conditions as described earlier. Factors affecting denitrification include soil microbes, the oxygen supply in the soil, soil pH, soil water content, soil nitrates, soil temperature, and amount of organic matter.[152] [153] Denitrification is the major source of nitrous oxide emissions from soils though certain types of bacteria during nitrification may convert nitrites to nitrous oxide.

Another avenue to reduce nitrous oxide emissions is through lesser demand for meat and dairy. As much as 50%-80% of the nitrogen in animal feed is excreted in the form of animal waste (urine and manure) instead of being absorbed into the animal bodies. A significant source of nitrogen in the soil of pasture land is livestock urine.[154] In fact, livestock urine may contain much more nitrogen than nitrogen from fertilizers. It has been estimated that a urine patch can contain about 1,000 kg of nitrogen per hectare as compared to about 30-50 kg of nitrogen from fertilizers per hectare.

About 60%-80% of the nitrogen in livestock urine is in the form of urea. Urea reacts with an enzyme in livestock faeces to form ammonia. The ammonia that is formed is an issue if there is too much. The ammonia is converted into ammonium ions in the presence of water, as stated earlier. The nitrifying bacteria then convert the ammonium ions into nitrates. The nitrates may be converted into nitrous oxide in certain conditions as described earlier.

Animal manure can lead to various types of pollution. Pollution from animal manure in the form of ammonia, nitrates and nitrous oxides is of major concern. Similar to urine, manure is a source of ammonia. Nitrogen in manure can be converted into ammonia through bacterial degradation.

The ammonia may dissolve in moist soil to form ammonium ions and through the processes described earlier produce nitrates as the end product. Or, the ammonia may be released into the atmosphere and react with nitric acid and sulfuric acid, to form ammonium nitrate or ammonium sulfate which are major components of the fine particulates $PM_{2.5}$. These fine particulates are harmful to human health. Manure that does not get access to oxygen will generate nitrous oxide in anaerobic conditions.

The overabundance of nitrates leads to eutrophication, which is an excessive enrichment of a body of water with nutrients. Nitrates are soluble in water and this substance may run off to streams, lakes or reservoirs. The overabundance of nitrates in the soils comes from excessive use of fertilizers, animal urine and manure. Algal proliferation that results is a serious problem and adversely affects marine and freshwater organisms.

The sudden and expansive blooms of algal growth can lead to lots of dissolved oxygen during the daytime as a result of photosynthesis. But at night time, owing to respiratory activities of the algae, the levels of dissolved oxygen in the water are reduced. These low levels deprive other organisms of their need for oxygen and some may die. When the nutrient flows decline, the algae blooms will die and microbes that aid in decomposing the algae use up oxygen. The decomposition process sucks up oxygen and this could lead to suffocation and death of other organisms.

Nitrates may get into freshwater for human consumption. Excessive nitrate levels are harmful to human health and lead to respiratory and reproductive diseases, kidney, spleen, and thyroid in children and adults. Nitrates are particularly harmful to infants.

What we have seen in this section is that fertilizers and uncontrolled run-offs containing animal wastes have also contributed to various forms of pollution including nitrous oxide, a very potent greenhouse gas. Excessive applications of inorganic nitrogen fertilizers result in nitrates which are necessary for the production of nitrous oxide through microbial activities. The animal wastes, i.e., urine and animal manure from animal farming, also result in nitrates formation. Not all are specifically targeted to fertilize the soils. The animal wastes washed away are not treated and cannot be controlled, leading to pollution of the atmosphere from ammonia and nitrous oxide, nitrates pollution in freshwater, algae blooms, etc. Widespread adoption of a vegan diet does help in managing the problems that arise from animal wastes.

11. “Is it Alright for Humans to Eat Meat?”

I was about ten when I asked the question, “Is it alright for humans to eat meat?”. I did not know about the word “ethics” then but I was thinking about whether humans should be eating meat since slaughtering animals brings pain to the animals. I was brought up the traditional way. My brothers, sisters and I were taught to do good to people. We were told we must treat people kindly and help whoever needs assistance. We helped out relatives and friends in whatever way we can. My late mother loved driving and gave lifts to my neighbours, family friends and my friends from school days whenever the opportunities arose.

There were several other related questions. Another question is, “Can humans be in good health without eating meat?”. I was thinking that if slaughtering of animals brings suffering to animals, my

other question was, “Am I harming animals if I eat meat?”. I was told by my family friends, relatives and family members that it was alright to eat meat as animals like pigs and chickens were there for us to eat. I did not think at that time that I got clear answers to these questions. I just followed what others were doing for their regular meals, i.e., I ate meat when I was a kid and continued doing so till I was 41.

I grew up in Kuala Lumpur, Malaysia – I lived at 4th Mile, Gombak Road (in Malay it is Batu 4, Jalan Gombak) for most of my childhood and during my teenage years. My family reared chickens and ducks in our backyard. Some of my neighbors also reared chickens and ducks. I saw chickens being slaughtered at home and at the wet market that was located about four miles away. In the slaughtering process, the necks of the chickens were slit and the blood drained away from the slit openings.

I had pondered about the enormity of the pain that the chickens and ducks had to go through as I watched them being slaughtered as a kid. It was clear to me that the chickens felt enormous pain. I could feel the enormous force that the chickens exerted to struggle away from being slaughtered. It was very clear to me then that the chickens wanted to escape from the hands that were about to slaughter them. The seed for me to adopt the vegan diet years later was beginning to take shape.

A mile further down Gombak Road, i.e., 5th Mile Gombak, was where some of my relatives stayed. Some of my relatives are still staying there. I visited my uncle, auntie, and my cousins at 5th Mile Gombak quite frequently when I was growing up. The neighbors of my relatives in that area reared pigs too. The conditions the pigs were kept in were not pleasant. I started asking as a kid if it was alright for humans to slaughter the pigs and eat them.

When I was about ten or eleven, I held a chicken for slaughter. I experienced firsthand the enormity of the force of a chicken wanting to escape from being slaughtered. At the instance when the chicken’s neck was slit, I could feel vividly the massive energy the chicken exerted as it struggled to escape was very much like a titanic force impinging on my hands. It was quite a dreadful experience for me and the chicken. That was the only time I ever held a chicken for slaughter. The gigantic power that the chicken exerted to free itself is still very much in my mind. Once is enough. Before this incident, I watched chickens, etc., being slaughtered from a distance and I could feel their pain. Having experienced holding a chicken for slaughter by myself, it is clear that the slaughtering of farm animals is an energy-sapping and a very painful experience for them.

I told my grandmother and mother that I would never want to hold the chicken again for slaughter. All these experiences as a kid looking at chickens, ducks and pigs being slaughtered are etched in my mind. The thought of the chickens’ necks being slit came across to me from time to time. I felt guilty whenever I ate meat and seafood from when I was ten until I turned vegan. After I turned vegan, I bow to the meat of slaughtered chickens, ducks, pigs, etc., whenever I see them.

There was not much information on the plant-based diet when I was in primary and secondary schools. My classmates and I were taught in school that it was essential to eat meat and seafood for a well-balanced diet. Meat and seafood were and still are part of the food pyramids in many schools. Also, killing animals for food has been going on for centuries and it was a well-accepted culture to eat meat.

Given my experience as a vegan so far, it is clearly wrong to state that one has to include meat and seafood as part of their diet. It is not necessary and a plant-based diet is enough to maintain a healthy lifestyle. A worthwhile question to ponder is whether a meat-based diet is in contrast related to a

higher probability of causing chronic diseases such as certain cancers, diabetes, and heart-related diseases, and contributing significantly to the pollution that Earth can ill afford.

I did not know much about nutrition when I was a kid. I did not know that a diet without meat can be healthy. I did not know what a vegan diet was back then. I never heard of the word vegan when I was a kid. I did read some books on yoga and some authors did talk about the benefits of a diet that does not include meat and seafood. There were some news articles that I read when I was a kid about meat increasing the likelihood of contracting some cancers like bowel cancer. Other than that, there was not much information about the vegan diet then.

Had I been told in school that it was healthy to be on a plant-based diet, I would have not eaten meat from the age of ten. But back then, information on plant-based diet was not available to me. I limited my meat intake as I felt guilty about consuming the flesh of animals, including fish and other aquatic creatures.

Those times when I had meat-free dishes before I turned vegan were always guilt-free and happy occasions for me. I went to vegetarian restaurants at times to buy vegetarian dishes when I was studying in Singapore and the United States. I think compared to most of my friends and relatives who eat meat, my meat intake was significantly less.

I believe my low meat intake since I was ten likely contributed to my good health. Had I eaten much more, I think the probability of me contracting the chronic diseases would have gone up significantly. I am not obese and this probably helps. I am about 5 feet 9 inches tall and I now weigh about 66 kg.

12. My Resolve to Go on a Vegan Diet at 41

When I was 41, I was not completely sure my decision to go meat-free diet would keep me healthy. It was a gamble. For about two years before I turned vegan, I had already reduced very drastically my meat intake to a few small pieces daily.

My plan initially was to adopt the vegan diet some years later. My resolve to become a vegan came much earlier than I expected as my late father passed away suddenly in September 2002 in a car accident. It was unexpected and I was devastated when my late father passed away. I wanted to do something to honor my late father. I thought of the various ways and means to do some good deeds and honor him.

As I have been having thoughts since small that humans should not consume meat or seafood, I was already psychologically ready for a meat-free diet. In terms of psychological readiness, going vegan for me is not an issue. The key question for me then was whether the diet was healthy. I have been lucky to have known closely a vegetarian and a vegan when I was in the USA, and a vegetarian when I was in Hong Kong. They are Gopi Maliwal, Patrick Brady and Vikas Kakkar. They all looked healthy. They gave me more confidence that it can be healthy to adopt a vegetarian or vegan diet.

I first met Gopi Maliwal, a vegetarian, in 1986 when we were both pursuing the MBA at Virginia Tech, Blacksburg, Virginia, USA. Gopi looked healthy though he was quite skinny. Gopi has been working in Hong Kong for more than two decades and I met him from time to time in Hong Kong before I left Hong Kong for Sydney.

I met him again in early May 2022 for afternoon tea near his office. During that meet-up in Hong Kong, he told me that the milk that he consumed is specially air freight from India. There is something very extraordinary about the milk that he bought directly from India – he said the cows in India that

provide his milk will not be slaughtered. I of course fully support the practice of not slaughtering any cows but I have some concerns about the consumption of dairy milk given the literature on the possible adverse health effects of milk.

Patrick Brady is the vegan friend whom I met while I was studying in Gainesville, Florida. I first met Patrick in 1989 at an apartment complex in Gainesville. At that time, I was pursuing the Ph.D. program in Finance at the University of Florida.

Patrick did not eat any meat, eggs or dairy products when I first met him. Curious, I asked him why. He told me that he was "allergic to meat". He sounded serious about his "meat allergy". At that time, I thought erroneously that his body was unique and inherently suited to be on a vegan diet given what he told me about "his body's allergy to meat". Of course, given my experience, that was wrong thinking. It is not due to his body being more suited to a plant-based diet. I believe that a person can be healthy on a vegan diet if the person could find the right composition of plant-based foods. That said, I know some ladies who lack iron on a plant-based diet. We need to look for sources of iron for some ladies who could not get enough iron on a plant-based diet. Patrick did give me a certain boost of confidence when I decided to go vegan though I was not completely sure.

I met Patrick again in July 2019 at Virginia Beach for afternoon snacks. I was visiting the USA at that time. I told Patrick during our afternoon tea that my health has been great since I adopted the vegan diet in 2002. It was only at that meet-up that he told me he was not allergic to meat medically. He was hesitant to inform people that he was on a plant-based diet and did not want to get into a long discussion on this diet. Patrick further told me he adopted the vegan diet as he did not want to cause suffering to animals.

I first met Vikas Kakkar, a vegetarian, at the City University of Hong Kong, Hong Kong. He joined as a faculty member in 1996 and became my colleague. Vikas consumes some dairy products and does not eat eggs but there is no meat and seafood in his diet. Vikas looked energetic when we saw one another at the department during those days. He still looks great and energetic.

13. A Tribute to My Friends Who Are on the Vegan Diet

I am lucky to know a number of friends who are on the vegan diet. They are a source of information for me and have provided me with advice on the vegan diet.

After I adopted the vegan diet (I was in Hong Kong at that time), I joined a meet-up in Hong Kong which was led by Shara Ng, Dr. John Wedderburn and a few others. John is a medical doctor and he advised me to take vitamin B12 supplements. I have been taking the vegan B12 supplements orally (about 500 micrograms every other day) since then. My B12 level is within the normal range according to the test results.

Another vegan friend who was in Hong Kong, Lucy Chang, advised me to eat flaxseed and I have been consuming flaxseed quite regularly for years. Flaxseed contains Omega-3 fatty acids and helps in reducing the risks of suffering from heart-related issues, cognitive decline, and certain cancers. Fish also contains Omega-3 fatty acids. As far as I know, there are 11 types of Omega-3 fatty acids.

The Omega-3 fatty acids found in fish and animal foods include eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are good for the human body. EPA and DHA lower the risks of cardiovascular diseases, improve brain function, strengthen immunity, reduce hair loss and are good for eye health. The Omega-3 fatty acid Alpha-linolenic acid (ALA) is found in plants, e.gs., canola oil,

chia seeds, flaxseeds, flaxseed oil, full-fat soy foods, etc, but it is also found in some animal fats. The human body can convert ALA into EPA and DHA.[155]

14. Social Circle, Gatherings, and Vegan Diet

(For more content on this matter, please refer to *Plant-Powered diet – a Journey for Health and the Environment*).

A factor that has to be taken into consideration by someone considering a vegan diet is the likelihood of getting the support of family members, spouses, dating partners, etc., for the change in diet. One's social circle could be smaller if he or she adopts the vegan diet. Dating relationships could also be affected. Depression may set in, e.g., if a person who was on a meat-based diet suddenly finds that friends and relatives are not calling the new vegan for social gatherings. It is also possible that in a community of vegans or vegetarians, the person who is on a meat-based diet may feel out of place.

Any person wanting to turn vegan must consider all these factors but, in the end, he/she will have to weigh all the factors that are relevant to him/her. Those who are dating may end up in a break-up if one's dating partner disagrees. One's priorities in life are a factor and the decision is not an easy one. It is best left to the individual to decide. There may be a need to seek counseling. The ideal situation is if both dating partners or spouses agree. But this is not always the case. To some, it may not be an easy issue to resolve. It is possible that a dating partner may turn vegan to keep the relationship with his/her vegan partner but it is best if the dating partner also feels happy doing so.

People react differently to new circumstances and the person will have to figure out what he/she wants and weigh all relevant factors on this issue. Some may weigh turning vegan to be far more important than the likelihood of a smaller social circle. For example, some are not affected to a significant extent emotionally by a smaller social circle. Others find it harder to accept. Some of my friends had told me that their social circles will be smaller if they adopt the vegan diet. This may well be true. But if more people are on this diet, then the issue of a smaller social gathering circle and dating pool will be less of a problem. Currently, a small dating pool of vegans is an issue. Unfortunately, this problem will not go away that quickly as the percentage of vegans in this world is still very small.

15. Vegan Advocacy

Though there is presently more information available, a lot of people have not heard of the vegan diet. Most have heard of the vegetarian diet. Given that the vegan diet is a powerful tool for preventive medicine and has numerous health benefits, as documented in research articles and testimonies of those who are vegans, it is imperative for those who are on a vegan diet to discuss the benefits of this diet with their friends, relatives and colleagues. I have been sharing my experience as a vegan with my friends, ex-students, students, colleagues, ex-colleagues and anyone who wishes to know more about this diet since I turned vegan.

Those who wish to go vegan should not be discouraged by cases of babies who were fed on a plant-based diet and later died from malnourishment. These cases are very rare. We are not sure if some of these cases were due to child abuse. Unfortunately, these cases happened and we all pray for these babies. Parents who wish to raise their children on a plant-based diet should regularly seek advice from their nutritionists, and bring their babies to visit pediatricians or doctors for medical examinations on a schedule as advised by their doctors.

Babies can be fed on a plant-based diet without any adverse issues but it must be well balanced. The Academy of Nutrition and Dietetics (formerly the American Dietetic Association) has stated that the vegan diet is healthy and provides adequate nutrition for all stages of a person's life, i.e., at the stage

as a fetus in a mother's womb, baby, child, teenager, and an adult.[156] [157] [158] Athletes can also be healthy on a vegan diet. The Academy further states that the vegan diet may act as a preventative measure against certain diseases.

You do not have to be a vegan to talk about past research on the benefits of a vegan diet. Discussing the vegan diet with friends and relatives even if one is not vegan may lead to some reducing their meat and seafood intake. However, there is a likelihood that one may risk losing friendship at the mere mention of the word vegan. Some are very used to having meat and do not like anyone to talk about the vegan diet to them. Some medical doctors I had spoken to were not convinced that a vegan diet is complete. They were advising their patients to include meat and dairy products. Sharing information about the importance of the vegan diet must continue regardless.

In the long run, I strongly believe that healthcare costs will come down drastically if more people reduce their meat intake. Governments do not then have to allocate a large part of their national budget to healthcare. Of course, going for a 100% plant-based diet is the ideal outcome but it takes time for people to get used to the vegan diet.

16. Compositions of Vegan Diets

People who are in different parts of the world consume different compositions of vegan diets. Vegan diets of Caucasians from North America and Europe are different to some extent from those of Asian origin in the East, e.g., China, Singapore, Malaysia, Taiwan and Japan.

16.1 My Typical Vegan Diet

I like to share with readers what I typically eat. I get advice on plant-based nutrition from websites such as www.pcrm.org and https://nutritionfacts.org/.

My typical breakfast includes some selections of the following: oats, wholewheat bread, multigrain bread, black sesame, black beans, almond powder, walnuts, chia seeds, flaxseed, etc. For lunch and dinner, I would have vegetables, rice, noodles, etc. I will try to include varieties of vegetables of different colors.

The vegetables which I consume for each meal include some selections of the following: ginger, lettuce, carrots, celery, cucumber, alfalfa, kidney beans, chickpeas, green beans, long beans, okra, kale, bean sprouts, turtle beans, eggplants, broccoli, mushrooms, tomatoes, cabbage, red and green bell peppers, bitter gourd, squash, basil, corn, potatoes, curry leaves (as flavor), spinach, oregano, parsley, avocado, etc. The nuts I consume include walnuts, almond, cashew nuts, etc. I choose organic foods at times. What I do encourage is for all to eat vegetables and fruits of multiple colours, if possible.

The fruits I consume include oranges, mandarin oranges, minneola tangelo, apples, kiwi fruits, papayas, lychee, longans, mangoes, dragon fruit, pineapples, dates, pears, bananas, passion fruit, persimmons, grapes, strawberries, peaches, rambutans, blueberries, raspberries, cherries, watermelon, honeydew, rockmelon, lemon, figs, grapefruits, apricots, nectarines, etc.

I avoid monosodium glutamate (MSG) as I will get very thirsty if I consume food cooked with MSG. Wholewheat bread is highly recommended and I will avoid white bread, if possible. Preservatives are very common in food items to preserve food but I will avoid preservatives to the fullest extent possible. There are a few bread brands without preservatives. So far, my body's reaction to preservative-free foods has been very good. I keep these food items in the fridge and consume

preservative-free foods before the expiry day. For bread, I finish it within three days. I got stomach upset once or twice a year in the past but I do not think it was related to preservative-free foods. When I buy almond milk and soya milk, I will try to avoid additives like stabilizers in addition to preservatives.

16.2 Possible Allergy to Certain Vegetables and Nuts

Some people may be allergic to certain nuts, fruits and vegetables. Those who display allergic reactions to certain foods should seek medical advice. Allergy to, e.g., peanuts can cause hives and for certain people, it can be fatal.

I am allergic to peanuts and hazelnuts. I would get rashes on my skin but luckily it is not life threatening. I found out about this allergy by chance through trial and error. I developed urticaria (or hives) on my skin about twelve years ago. I visited a medical doctor trained in Hong Kong and he gave me anti-histamines. This drug did control my symptoms but when I stopped taking this drug, the rashes came back.

I talked to one of my ex-students about my problem and he suggested that I see a Chinese Traditional Medicine (CTM) doctor. The Chinese doctor advised me not to eat bread. I would eat bread with peanut butter. After I stopped taking bread, the rashes went away. At that time, I did not know peanut butter was the culprit for my rashes. After that, I did not eat bread for a number of years. It was by chance that I was cured of my rashes as the Chinese doctor did not know I was allergic to peanut butter.

About five years ago, I tried eating bread and again I used peanut butter and hazelnut spread. The rashes came back. At that time, I guessed peanut butter and hazelnut spread were the culprits. I experimented with using almond and cashew nut spread. I was right. I did not develop those rashes when I use almond and cashew nut spread. So, I stopped consuming peanuts and hazelnuts altogether.

16.3 Should Vegans Avoid Garlic, Onions, Spring Onions, Leeks and Chives?

About eight years ago, my Buddhist friends said that it was best to avoid consuming garlic, onions, spring onions, leeks and chives (the five vegetables) for health reasons. Since then, I would avoid consuming these five vegetables as best as I can. I am not sure about the reasons put forward by my Buddhist friends. They told me that these foods may upset the digestive tract and kill the good bacteria in the gut. I am not sure if this advice is true. There are rare occasions when I ate some bits and pieces of these five vegetables during flights and at friends' places. More scientific research has to be carried out to see if these food items could cause harm or bring benefits to the human body.

While some have no medical issues with consuming garlic and onions, others may suffer from digestive problems from garlic and onions.[159] Garlic and onions are very high in a sugar molecule called fructan. There have been cases of patients having trouble digesting and showing symptoms of intolerance of fructan, which include bloating, diarrhea, constipation and intestinal pain. It is good to monitor if one might develop these symptoms when consuming garlic and onions. It is possible to be allergic to garlic but it is very rare. A few cases have been reported.

When I adopted the vegan diet in 2002, I did not adhere to avoiding these five vegetables altogether. I did eat spring onions but it was not that much. I do not like to eat garlic and onions as these vegetables have a strong taste. It was fine to me if onions and garlic are cooked together with other

vegetables and I ate the other vegetable items without eating garlic and onions. I rarely ate leeks and chives, probably five times a year from small till about seven years ago.

Buddhists who are on a strict vegan or vegetarian diet, in general, do not consume these food items. However, what has been prescribed many centuries ago may not be applicable today owing to changes in the environment. We have to be flexible. If these five vegetables could cure certain diseases, vegans and vegetarians should eat them.

Venerable Master Chin Kung (净空法师), a highly respected Buddhist monk, said that it might be alright to consume these five vegetables in certain cases.[160] The Buddha, according to Ven Chin Kung, said that these vegetables affect those who are in the early stages of cultivation in that disciples would find it harder to concentrate. Hence, Buddhists, especially those in the Mahayana tradition, are advised not to consume these five vegetables.

Ven Chin Kung said that garlic has certain medicinal properties and may cure certain diseases. Ven Chin Kung said a medical doctor, Dr. Tang, described a case of how garlic cured a patient. Dr. Tang once had a patient who suffered from end-stage tuberculosis. Doctors told the patient that they thought he only had three months to live. Dr. Tang's patient consumed garlic regularly and recovered. It is not clear whether garlic helped the patient but it is a blessing that the patient ate garlic and recovered. Dr. Tang thought that garlic cured the patient.

Vegans who follow the Buddhist practice may wish to seek medical advice if they wish to eat these vegetables in large quantities to combat certain diseases. It may well be useful for medical treatments and so it must be administered by a trained medical specialist. They should monitor their health to see if there are adverse effects when they consume these vegetables.

I recommend ginger for those who avoid these five vegetables. I eat ginger almost daily. Ginger has anti-inflammatory and anti-oxidative properties. An anti-inflammatory substance reduces inflammation or swelling. Briefly, oxidation is a chemical reaction that leads to a chain reaction that damages the cells of an organism. So, the anti-oxidative property of ginger is good.

In addition to the reasoning that these five vegetables could cause harm to a vegan's health if taken in large quantities, another belief is that these vegetables may affect adversely one's meditative mind, awareness and consciousness. Buddhists cultivate to be aware of their actions and emotions to the fullest extent possible. For example, when one is angry, the person should know that he is angry. The problem arises when a person does not know the magnitude of his or her anger, particularly when he/she is in a state of extreme anger. According to most Buddhist masters, avoiding these five vegetables can help to control one's emotions. However, someone who is sick should certainly consume these five vegetables if these vegetables can help to cure certain diseases.

16.4 Possible Iron Deficiency

Iron deficiency is an issue for certain vegans. I have been told by several women I know that they suffer from iron deficiency when they were on the vegan diet. They got tested for iron deficiency and doctors advised them to eat meat when their test results showed low levels of iron. They gave up the vegan diet and resorted to eating meat, including beef.

To women who suffer from iron deficiency on a vegan diet, my recommendation is to try out vegetables that contain high levels of iron before giving up on the vegan diet. Vegetables that contain a high amount of iron include soya beans, chia seeds, beans, peas and lentils, pumpkin, black and white sesame, flaxseeds, almonds, cashews, pine nuts, macadamia nuts, spinach, kale, Swiss chard,

collard, beet greens, tomato paste, potatoes, mushrooms, palm hearts, fruits, chocolate, oats, coconut milk, quinoa, whole grains, spelt, dried thyme, etc. Also, to increase iron absorption, it is good to eat foods rich in Vit C, minimize the intake of coffee and tea during meals, consume lysine-rich foods like quinoa, lentils, avocados, nuts, seeds, and leafy greens etc.[161]

16.5 Importance of Calcium in Our Diet

Calcium is often associated as an essential mineral for healthy bones. Calcium aids in fighting cancer too as it regulates cell growth. It helps our cells, muscles and our nervous system to function normally.

Plant-based foods that contain calcium include soybeans, tofu (soybean is an essential ingredient for tofu, and possibly from manufacturer-added calcium), beans, peas, lentils, kale, figs, almonds, broccoli, chia seeds, flax seeds, tahini, amaranth and teff, leafy greens, seaweed, etc.[162]

17. The Way Forward: Recommendations and Further Research

I would like to provide several suggestions to governments, medical associations, medical schools, universities, schools, education authorities, corporations, and the general public on what we can all do for our health and our environment. International agencies such as those that are under the United Nations could work with governments, universities, corporations, etc., on how to educate the general public on the vegan diet and implement certain research projects.

a. It is time for governments to recognize that a plant-based diet is healthy. Governments could set aside some funding to bring more awareness about this diet among the general population. I do not think this will cost much as they could prepare brief notes that can be uploaded onto a website for users to download online. Governments could prepare a list of past research findings on the vegan diet and use this list to inform their citizens and residents. There is of course no need to print on paper.

   Governments will have an incentive to do so as the productivity of the workforce will likely increase as fewer workers will be taking sick leave. For those who are on a plant-based diet and taking sick leave, it is likely they will take a shorter number of days of sick leave. The budget for health care can be reduced and the stress on the healthcare system will be eased.

   Governments may wish to fund these research projects, and perhaps work with certain international agencies:

   i. Research the affordability of vegan diets for those in the lower income groups in different countries.
   ii. Research cheaper ways to produce the food items that constitute a balanced vegan diet.
   iii. Research how to make the vegan diet more accessible, particularly in developing nations, etc.

b. Medical associations could upload say a short leaflet for general practitioners to inform their patients about the benefits of a vegan diet for health, listing the past research on vegan diets and testimonials from those who are vegans. They are welcome to incorporate relevant excerpts of what I have written here.

c. Medical schools should include a course on nutrition and invite experts to show how a vegan diet can be a preventive tool for various chronic diseases. This course could be offered to both practicing doctors, specialists and students. They may advise their students that a plant-based diet is a powerful tool for preventive medicine.

   Medical schools could initiate the following research projects, with funding possibly from the government and the private sector :

   i. Follow the sample of babies and children who are on a vegan diet well into their adult life and look at their health progression, controlling for factors such as alcohol intake, smoking etc. The privacy of the individuals will be given due respect.
   ii. Study the effects of a vegan diet on certain neurological disorders such as Parkinson's Disease and Alzheimer's.
   iii. Study the effects of a vegan diet on those who are suffering from autism.
   iv. Do more research on the composition of plant-based infant formula and come up with affordable infant formula that will be able to meet the dietary requirements of babies and growing children.
   v. Work with certain international agencies to do more research on a daily vegan diet make-up that is nutritious and affordable, taking into consideration the different cultural backgrounds of societies across the globe.
   vi. Engage nutritionists and doctors to come up with targeted compositions of vegan diets tailored for those suffering from heart-related ailments, chronic kidney diseases, certain cancers, etc.
   vii. Research the factors, e.g., physiological factors, that lead to iron deficiency for those who are on a plant-based diet.
   viii. Research the combination of plant-based foods that can fix the iron deficiency problem that some people, particularly women, face when they are on a vegetarian or vegan diet.
   ix. Research if some people could be prone to suffer from certain nutritional deficiencies when they are on a plant-based diet.

d. Universities worldwide could also participate and inform their students about the benefits of a plant-based diet for health and the environment. The plant-based diet is a powerful tool in combating climate change and for their students' overall health. Most universities and large corporations, in general, have been actively incorporating concerns about the environment, social causes and governance issues in their mission statements and their daily operating activities. These criteria are grouped under the Environmental, Social and Governance (ESG) umbrella.

   The ESG standards are a set of criteria that a company may wish to follow for its business activities. There is not a universal same set of criteria for organizations to follow. There are higher or lower levels of commitment and different organizations have different criteria. Some organizations may choose not to follow certain criteria.

   An example of the environmental criteria for a company is its commitment to environmental protection. Some may wish to lower or offset their carbon dioxide production in the future while other companies may go to the extent of using technologies and other means to remove all of the carbon dioxide that it has produced for decades since their incorporation.

The environmental, social and governance (ESG) standards can be strengthened further if organizations, including universities, promote the vegan diet on their respective premises. The vegan diet benefits the environment and the Environmental standards of ESG are inseparably linked to a plant-based diet. As stated earlier, a plant-based diet can bring about a drastic reduction in the emissions of greenhouse gases.

e. We can start from young. The education authorities and schools have a role to play to inform students about the benefits of a vegan diet for health and the environment.

   To convey what constitutes a well-balanced diet, it is not necessary for education authorities and schools to include meat, seafood, dairy and eggs in the food pyramid. Based on past research findings, these food items are not necessary for a person to be healthy. It is fine to include meat, seafood, dairy and eggs as part of a diet for a person, if necessary, but the food pyramid should contain no reference that a meat-based diet is a healthy diet.

   The authorities will want to have another food pyramid that is only plant-based and list all the vegetables, fruits and nuts that form a well-balanced diet. Vegan Vitamin B-12 should be included and possible allergies to certain nuts, etc., should be listed. Let the readers and parents judge whether this diet is healthy.

   They will want to inform students and parents that a well-balanced plant-based diet is a healthy diet based on past research findings. It is important to inform students that they may need vegan vitamin B-12 and vitamin D. Those living in the tropics can get vitamin D when they are exposed to sunlight but those living further north or south of the equator may not get sufficient sunlight during fall, winter and spring. So, supplements may be necessary.

f. Corporations and financial institutions will want to inform their employees about the benefits of vegan diets for health and the environment. The ESG standards mentioned previously are inseparably linked to the plant-based lifestyle. I strongly believe a healthier workforce will be an added bonus to all firms.

g. The general public has a role to play. Humans are responsible people and they want to play their part to preserve the environment for their future generations. When it comes to the environment, we all want to leave behind a better legacy for our descendants, our children, grandchildren, great-grandchildren, etc.

   Our descendants want a healthier environment. Those who are adopting the vegan diet are doing environmental charity daily. A small step by an individual to adopt a plant-based diet, when summed up across billions from all over the world, is powerfully significant.

18. To Wrap It All Up

When I began my meat-free diet, I thought there was a possibility that I would become sick. Instead, I have enjoyed many years of good health since then. I would rate going vegan as one of the most important decisions in my life. Certainly, our family and our well-being, including financial security, are most important and all these should rank at the top of one's priorities. Next, to me, is the decision to turn vegan. If you are not yet on a well-balanced vegan diet, I encourage you to explore further and weigh the pros and cons. To me, it is a happy and healthy diet.

Some who are on a vegan diet do however suffer from certain chronic diseases but again factors like how long one has been on a vegan diet, composition of the diet, genetic make-up, etc., are crucial factors to be considered too. The good news is that there are more testimonials from vegans. Articles in medical and nutrition journals in recent years show that the probabilities of suffering from certain chronic diseases are significantly reduced for those on a vegan diet. That is a strong reason to go vegan.

It has taken me quite a number of years to adopt the vegan diet. I hope that after reading this article, those who wish to go for the vegan diet but are unsure as to whether the diet is healthy will not have to wait that many years.

For good health, I strongly recommend the vegan diet as a crucial component but the other critical ingredients include clean water, clean air, income to buy food, etc. I hope that more and more people are aware that going meat-free can be healthy as long as the plant-based diet is well balanced. To those who are not yet on this diet, do read about the benefits of the diet, and give it a try but accompanied by medical advice and supervision, if necessary. The diet must be well balanced and supplemented with vegan vitamin B-12. Vegan Vitamin D may be necessary.

Parents could feed their newborn babies on a vegan diet as vegan baby formula are now available. It is healthy to raise newborn babies and young children on a vegan diet. Parents should not compel their children who are not already on a plant-based diet to adopt the vegan diet if they do not want to. Those in their teens have their own social circles and it is not easy at all for teenagers to adopt the vegan diet.

Individuals should be given the space to decide for themselves as to whether the plant-based diet is suitable for them. It is challenging for those already used to a meat-based diet to adopt the vegan diet. It is fine to inform them but one should not compel them. Parents who are on a vegan diet and want their children to adopt this diet will need to be patient. The need for years of conversation over dinner is likely the case. It is fine to wait but do inform them.

There are testimonials from those who have been on a plant-based diet since birth. Currently, research articles on the vegan diet, testimonials from vegans, and advice from doctors and nutritionists advocating a vegan diet are readily available. We can use all these sources of information to inform children.

I do support health insurance companies adjusting the health insurance premium for those who are on a vegan diet. Given the research on the lower probabilities of contracting chronic diseases (non-genetically related) like some cancers, diabetes, and heart-related ailments, factoring in a person's vegan diet as a factor for adjusting the premium is welcome.

Some people may find that they will also enjoy inner peace too in addition to good health. As to what inner peace is, it is best left for the individual to feel it. In summary, a well-balanced vegan diet is good for better health on average for the world's population and the environment. Inner peace is a bonus for some.

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