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Save the World: Role of Mathematical Works and Calculations

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ABSTRACT: Mathematics for the Environment shows how to employ simple mathematical tools, such as arithmetic, to uncover fundamental conflicts between the logic of human civilization and the logic of Nature. These tools can then be used to understand and effectively deal with economic, environmental, and social issues. There is a huge debate on renewables: pros and cons are highly controversial but often quite un-scientific. Arguments against renewable energy technology range from skepticism towards anthropogenic climate change to "Not In My Back Yard"-attitudes. Mathematics brings solid science to the debate. It provides confidence in climate change models and it helps to improve existing renewable technologies. Maths is also key in assessing renewables based on observations from the environment. For example, weather data helps to predict efficiency of solar cells. To establish a sustainable energy mix through clever energy storage and smart distribution, mathematical models help communities to plan for their future – because one way to solve the energy challenge is to think small: community energy projects build on maths for renewables to provide clean and sustainable electricity and heat for a city, a town or a region.

KEYWORDS: mathematics, environment, social, renewable, sustainable, energy projects, technology, logic

I.INTRODUCTION

Mathematicians doing their bit to save the planet in a multitude of ways:

1. Designing better weather forecasts and climate models

Accurate weather forecasts predict when and where extreme weather may strike, whilst climate projections are key to identifying weather patterns changing on a longer time scale. Our ability to predict weather and climate has advanced in leaps and bounds in the last few decades, thanks to maths. Modern weather forecasts rely on computers to solve the complex equations that simulate the atmosphere's behaviour – from global processes that influence the flow of the jet stream down to local rain clouds.Mathematicians play an important role in this process, working with a set of equations that describe the atmosphere, taking into account temperature, pressure and humidity. [1]Global Circulation Models (GCMs) describe the interactions between oceans and atmosphere to look at what the average conditions could be in decades to come.

2. Getting 'bang for buck' out of supercomputers

The computers used to model weather and climate get more powerful every year – but sheer processing power isn't everything. Maths makes these computers far more effective both through contributing to technological improvements in areas like quantum computing, and by rethinking the algorithms used in computer programs. For instance, new research allows the computer to automatically zoom its attention in on areas where the weather is particularly interesting, such as around storms.Optimising computers' performance can also reduce their energy demand. For example, the Met Office's Cray supercomputer runs on 2.7 MW of electricity, so even modest efficiency gains could have a massive impact on its overall energy consumption.[2]

3. Making the most of renewable energy sources

Optimising the layout of wind turbines enables them to harvest more energy

Renewable energy sources lie at the heart of a low-carbon world. By choosing optimal locations for wind or solar farms and designing the most effective layouts for tidal and wind turbine arrays, mathematicians ensure that these technologies harvest the maximum energy as efficiently as possible.Mathematicians contribute to research into energy supply and demand that ensures networks incorporate higher proportions of weather-dependent energy sources such as wind or solar power, making sure that the lights stay on in years to come.[3]

4. Preparing for change

The effects of climate change will be felt on many levels, and knowledge is key to safeguarding human health and livelihoods as we adapt to changing circumstances. Mathematicians use their understanding of probability and uncertainty to advise policymakers on the likelihood of heatwaves, floods or other changes in weather patterns, and help them to plan accordingly.Businesses also need detailed information on how climate change might affect them. The food industry for example is highly dependent on agriculture, and could use advance warning of an upcoming drought for instance to prepare themselves for smaller yields. Mathematicians try to predict who might be at risk so they can prepare for the future.Moreover, mathematical simulations are a valuable tool for estimating the possible consequences of specific actions, by playing out different scenarios.[4] This too can help policymakers choose one course of action over others. By presenting the hard numbers, mathematicians with an environmental conscience can seek to influence the ways businesses operate.

5. Making sense of 'big data'

Collecting billions of pieces of data in environments, from ice sheets to cities, can deliver precious insights into our planet's physical processes, human behaviour and everything in between. Climate scientists rebuild the history of our planet's atmospheric composition by analysing the tiny bubbles trapped in ice records, in order to anticipate the scope of future changes. But without the statistical methods that mathematicians bring to analyse this data and assess its reliability, the information has less value.[5]

6. Developing new technologies

Mathematical modelling is key to the development of new technologies such as CCS

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New technologies are key to a low carbon future. carbon capture and storage (CCS), for instance, could safely lock away greenhouse gases emitted by fossil fuel-fired power stations, and is likely to play a key role in averting dangerous levels of global warming. Detailed mathematical models make this research possible by using sophisticated logistics methods, network analysis, statistical modelling and many other mathematical tools.[6]

7. Making maths accessible to everyone

Crucially, maths can't save the planet on its own. Many of the global challenges we face are multi-disciplinary: overcoming them requires mathematicians to collaborate with scientists and engineers in different fields. And although the basic science behind climate change is well understood, convincing the general public and decision makers to take action to reduce carbon emissions is very much a work in progress. With their firm grasp of concepts such uncertainty and probability, Mathematicians are uniquely placed to communicate the science, data and forecasts, and ensure that this information is meaningful to the people who need it.For maths to have a real impact on our planet's fate, mathematicians therefore need to communicate the importance of their work clearly and effectively, knowing when to swap complicated equations for persuasive story-telling, pictures, games or genuine interaction. Opening up maths up for the world to understand might just be the best way that we can come to our planet's rescue.[7]

II.DISCUSSION

Mathematics problems involving basic computations, percents, ratios, tables, circle charts and graphs are used to illustrate environmental issues such as population growth, wastefulness, resource scarcity, air and water pollution, and electrical energy demand. A course, "Mathematics and the Environment," that has been given successfully in various schools, colleges and universities. In 1936, Lee Faulk created the world's first superhero, The Phantom, decked in a purple outfit and a matching mask. Subsequently, over the years, several spandex-wearing superheroes have graced our TV screens, saving the world one at a time. However, a new superhero has emerged, ready to save the world, and it's not wearing Spandex this time. Wondering who this mystery superhero is? It's mathematics.Mathematics can save the world:-

It helps to design better weather and climate forecasts.

We should all know that weather conditions are more than just rainy days or sunny days. Rather, they can significantly impact the environment in so many ways. For instance, extreme weather conditions are a leading cause of environmental imbalance. When this occurs, all industries and life forms suffer greatly.However, thanks to mathematics, we can create accurate weather forecasts that help us predict when and where extreme weather can strike. [8]In the same vein, we can also generate climate projections to understand weather patterns over a long period.Wondering how it works? Well, it's simple (kind of). Mathematicians work with sets of equations related to the atmosphere while considering all atmospheric conditions. Furthermore, using mathematical models known as Global Circulation Models (GCMs), they can then study interactions between the atmosphere and oceans and then predict future weather conditions.

Breaking down and analyzing big data

Every day, scientists around the world collect big data about the environment. This data is essential because it helps us understand the state of our planet and create strategies for preserving it or fending off disasters. However, regardless of how important or precious this data is, it's useless without a statistical interpretation.Fortunately, with the help of mathematicians, we can use statistical models to interpret data and determine its reliability.

It helps to prepare the world for a change

You've certainly heard about climate change, as it's been in the news for years now. Climate change is indeed real and will affect all sectors across the world. We can only mitigate these potential risks by accurately predicting them and taking steps to prevent or cushion them. This is where mathematicians come in.Since probability is a core mathematical tenet, mathematicians can use their understanding of this concept to draw analyses on the possibility of climate conditions such as heatwaves, droughts, and so on. Subsequently, they can advise policymakers on the proper steps to take.The bottom line is that the mechanics of climate change is inherently mathematical, and as such, we can rely on mathematicians to help predict these changes and prepare us for what is to come.[9]

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Maximizing and utilizing renewable energy sources

Today, environmentalists are concerned about the future of energy sources. On the one hand, we have renewable energy sources, and on the other, non-renewable ones (e.g., coal). To protect and preserve the non-renewable energy sources, we must look towards maximizing the renewable ones (e.g., wind energy and solar energy) since they are inexhaustible.Fortunately, mathematics can swoop in and save the day once again. For starters, mathematicians can design highly efficient layouts for turbine arrays and choose the best locations for solar farms. By doing these, they're ensuring that these renewable energy sources are maximized and used efficiently.Furthermore, mathematicians are constantly researching and trying to implement strategies for big corporations to integrate more weather-dependent energy sources in the future. Through all these immense contributions, math gradually builds a low-carbon world and ensures that the lights never go out.

Fighting natural disasters

In 2018, disaster struck in Paradise, California. A wildfire started, killing over 85,000 people and burning more than 150,000 acres of land. This disaster and many others have rocked the world, affecting lives and properties over the past decade. You may be wondering: how can mathematics help in these scenarios?Well, it's simple. In 2018, after the Paradise wildfire struck, a man named Gregory Crutsinger arrived and programmed 15,000 drones to fly over the wildfires. The drones took thousands of images, and these images were used to create a map for officials to assess the damage and create recovery strategies.As Crutsinger did, many mathematicians and scientists can design drones or mathematical models to assess the damages caused by natural disasters and proffer solutions or damage control.[10]

Utilizing and improving supercomputers

As the name implies, supercomputers are computers that perform at a very high operational level. You could think of them as the superheroes of computers. In most cases, they are used for scientific and engineering purposes (e.g., modeling weather and climate).Using mathematical concepts like quantum computing, mathematicians can improve these computers and make them more efficient. Consequently, their energy consumption can also be reduced by optimizing their performance. Talk about killing two birds with one stone!

Final Thoughts

Mathematics is more than just a technical subject. Over the years, it has saved the world and is still doing so today. As such, it's vital to ensure that your kids take regular math for kids classes or even learn online using edtech tools. This way, they'll be able to build a strong relationship with the subject and learn to love it. They could even become a mathematician someday and join the superhero trope![11]

III.RESULTS

In 2015, the UN approved the 2030 Agenda, indicating the 17 Sustainable Development Goals (SDG), which include everything from eliminating poverty to combating climate change, education, equality for women, protecting the environment and the design of our cities. This agenda is an opportunity for countries and their societies to embark on a new path towards improving everyone's lives, without leaving anyone behind. The Covid-19 pandemic has starkly highlighted the need for this initiative. Mathematicians had already anticipated this proclamation in 2013, the year of Mathematics of Planet Earth. This international initiative is being run by mathematics research organizations and institutes in the United States and Canada, with the support of UNESCO, the International Council for Science (ICSU) and the International Mathematical Union (IMU). The role that mathematics plays is essential: every phenomena on Earth is subject to mathematics, which is the only language we can use to describe them. Moreover, mankind must factor mathematics into any approach it takes in addressing said challenges. Climate change, protecting biodiversity, tackling pollution, controlling epidemics, ocean sustainability, averting natural disasters (volcanoes, earthquakes, tsunamis), and manmade disasters (fires) are all subject to equations. In short, the sustainability of planet Earth depends on mathematical science.The Earth is subject to constant change: its interior mantle, terrestrial crust, atmosphere and the life that it sustains are all subject to dynamic processes. Describing these processes requires mathematical models, most of which are enormously complex. Developing models that come ever closer to recreating real processes allows us to understand the processes better, meaning we can anticipate them, control them, and alleviate their potential effects.Mathematics not only helps us to understand natural phenomena, it also allows us to sustain the majority of human activity on the planet. Transport networks, the Internet and business transactions are all practical applications of research, graph theory and number theory.And, finally, we could refer to its key role in education; mathematics are,

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together with language, the two pillars of any educational system.As we can see, many knowledge areas concerning the Earth require mathematics for their development.[12] The 17 SDGs of the 2030 Agenda have a lot to do with the work topics of the Mathematics of Planet Earth program:

- **A planet to discover**, focusing on oceans; meteorology and climate; mantle processes, natural resources and solar systems.
- **A planet supporting life**, covering issues such as ecology, biodiversity and evolution.
- **A planet organized by humans**, looking at political, economic, social and financial systems; organization of transport and communications networks; management of resources; and energy.
- **A planet at risk**, covering climate change, sustainable development, epidemics; invasive species and natural disasters.[13]

It´s in these critical years that society is gambling with the planet's sustainability, and mathematics is at the heart of the issue. The initiative has determined three key challenges that mathematicians should tackle with enthusiasm:

- Promoting mathematical **research** in order to identify the major problems facing the planet and their solutions.
- Encouraging teachers at all levels of education to **raise awareness** of the key issues.
- **Informing** the general public of the essential role that mathematics has to play.

One of the great lessons of the current pandemic is the need for mathematical models, which predict the evolution of the infection. They also help optimize resources through operational research and the key to knowing exactly how effective vaccines are is through the use of statistics. [14]

IV.RESULTS

It is my fundamental belief as a teacher that I am duty bound to make my instruction applicable to tangible, important, and emergent issues in the communities which our students are part of. As a teacher of mathematics, I have been continuously challenged to make the content of study more accessible to students by providing significant context to their studies of algebra and geometry. Of all contexts available, no issues are more pertinent, to the well being of the current and future generations of students, than those of environmental impacts of human action. If we are not preparing students to apply mathematics in defining and solving real problems in their environment, we might as well not trouble them with the effort to learn the skill sets of algebra or higher mathematics.[14]Perhaps this point could be put more simply with the question: What are we trying to accomplish as teachers of mathematics? The obvious answer is that we are trying to guide our students in learning mathematic concepts and skills. Yet we are all too often disappointed in the outcomes of our efforts as reflected in the achievement of our students. On the many, many occasions when students ask, "Why do I have to learn this?" we should resist the urge to take a defensive or authoritarian attitude. Our students' learning and our own sanity will be much better served by authoritative responses that neither avoid nor artificially pacify our students' questions. In fact, what we should be doing is asking our own form of the question, "Why do I have to teach this?"This flies in the face of conventional mathematics instruction, which tells us that math is an absolute staple of academia. However, while the esoteric appreciation of the pure form is something that those of us who teach it can enjoy, it is not a valid approach to teaching the majority of our students. Our intent might best be focused on more immediately improve the lives of our students and the communities of which they are members, than on enforcing an aesthetic of mathematics. And, at our given time in history there is no greater exigency than the environmental impact of human actions. This is the most legitimate context we have available for the type of strong problem solving skills that can be developed in mathematics study. But, recognizing this is only a start.[15]
It is invaluable to encourage students to ask, "What is, and has been, the impact of human energy use and industrialism on the natural world?" The connections that exist, between how we live and the state of the world in which we live, are vast and can quickly become overwhelming. However, for our students today, avoiding thinking about the ecological state of their world is much like procrastinating over completing a homework assignment - the longer it goes untouched, the more likely it is that there will be too little time to do anything about it.This is cause for both pause and action in how we should proceed. In our capacity as teachers, the enablement of others to use the skills that we teach takes precedence over running out into the world to solve every problem by employing these skills ourselves. Whether or not our students become scientists, industrialists, economists, or policy makers who solve the world's problems, it is to us to educate them for any of these potentials as best we are able. We will be better able when we provide them the perspective to articulate and attack problems - which are exemplified best, and at a high-level of rigor, by environmental concerns.To implement environmental contexts in mathematics curricula does not require that we become experts in the field of environmental science. Indeed, as a comparatively new field of study, which requires

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multidisciplinary knowledge and research, there are relatively few experts on the subject in the world. [1] There is such a high degree of knowledge necessary to navigate any one of the sub-specialized areas of research that synthesizing them altogether is still a process-in-development for even the most knowledgeable researchers.[16] What is required is that we have a general acceptance of the scientifically grounded reality of environmental impacts, cumulatively called "climate change," and that we familiarize ourselves with some of the complexities of what, thus far, I've referred to as environmental issues in a very general way.My lack of specificity, on the one hand, is a conscientious choice and, on the other hand, it is out of necessity. That is to say, it is necessary to be a bit general in order to broach the subject. What we may now commonly refer to as climate change requires some abstraction if I am going to write about it in a paper that is somewhat less than the size of a telephone book.To fully understand environmental issues, which no one "fully" does, goes beyond having a mental image of melting polar ice caps. Although this is a legitimate part of the overall picture, it is far too simplistic to represent what is truly an enormous, variable, and still increasing catalog of issues. It is an important objective for us, before we set objectives for our students, to tackle a broad notion of what climate change means.A search query on Google generates forty six million three hundred thousand hits, even when "climate change" is entered in quotation marks, [17]which force the search to only find the exact phrase. [2] While this is currently outshined by the two hundred sixteen million hits for "michael jackson," it still represents an enormous amount of data.Besides being vast, climate change has remained a politically contentious issue for longer than a rational length of time. To get past this contention, let me start by saying that, if a teacher is conflicted about the politics or supposed debate on climate change, there are several options open to her or him: explore some of the multitude of reportage in the popular media based on correlations and causation; read some of the overwhelming academic papers that verify human actions as a perpetuating influence on climate change - the best of which may be the coordinated research findings of respected, independent scientists contained in the Intergovernmental Panel on Climate Change report of 2007 [3]; directly consult scientific experts who are open to sharing their findings; or, if you are either truly skeptical until more obvious effects of climate change become part of our everyday lives or find yourself politically polarized on the issue, there is always the option to go on in denial.[18]

In actuality, even if we exhaust the research in order to satisfy our skepticism, retirement will arrive before we will be able to make up our minds. There is so great a spectrum of knowledge, with more continuously being developed, that no one can take it all in over any short period of time. However the knowledge monumentally points to the industry of humanity as a primary catalyst for climate change. The reasons why this has been so thoroughly resisted in political debate is open to any number of accusations - from ignorance to malicious corporate conspiracy - a topic beyond my scope here. All confrontational jibes aside, and to invoke President Obama's diplomatic manner of speech, "Look… the point is not to argue whether climate change is somebody-in-particular's fault, the point is to consider the realities of it and find solutions that will provide a better future for all of us."To consider the realities, briefly, a note on usage of the term "climate change" is appropriate. We have lived with the term "global warming" for a significant amount of time, but we will likely hear it less often in the future. The warming of oceanic surface temperatures, overall average temperatures, and a myriad of warmer temperature consequences are a big part of the climate change puzzle. However, other consequences arising directly from human activities and energy use, as opposed to coming about via global warming, are also hugely important issues in the realm of environmental and human health. These include water pollution from industrial effluence, soil degradation and erosion from homogenous mega-farming, and species loss from human encroachment - among many other issues.[19] There are also issues that arise as chimeras, monstrous combinations, of environmental impacts - some of which are relatively well understood and some of which are not yet fathomed. Air pollution, to which I will give some attention later, is an example of climate change that results directly from the spreading of airborne particulate matter in fossil fuel exhaust and is indirectly exacerbated by the effects that warming air temperatures have on urban weather patterns. [4] Furthermore, even those consequences resulting from the rise in average temperatures do not always "feel" like "warming."The earth's average global temperature has risen by 1.13 degrees Fahrenheit since the beginning of the industrial revolution. [5] A strong analogy can be made for why this is so important, and why it might lead to such serious consequences, by considering an elevation of about one degree in internal temperature for a human being. With a rise of 1.13 degrees in body temperature, a person would be at, on average, 99.73 degrees, nearly 100. This also serves as an analogy for the variance in environmental outcomes. The symptoms range from flush dry skin to skin drenched with sweat, from severe thirst to an inability to eat or drink comfortably, from unbearable warmth to painful chills, from restlessness to exhaustion - all, seemingly different, symptoms of an overheated system or fever.The power of altering the terminology away from "warming" is quite serious. In a positive sense, the word "change" is more inclusive of the other grave concerns, not necessarily directly related to warming, which we should also be giving our attention to. "Change" also more accurately represents the

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effects that many people will observe as a result of the rise of average global temperatures (which will actually mean cooling temperatures in some regions and which is certain to mean erratic changes in many regions). In a negative sense, taking away the ominous note that is rung by "warming" may also take away exigency from popular perception of the issue. [6] By any other name, the problems - of human health, population and sustainability of our ecological and economical existences - are still as serious. The goals I propose are meant, through a regular and sustained practice, to help students build the math skills to solve them.[20]

V.CONCLUSIONS

The first, low level of environmental context is to provide simple, limited reference to an issue that falls within the broad realm of climate change. Examples might include representing the exponential growth or decay of a species population in equation form, graphing the rate of change in crop yields for a given region, or calculating the average number of commuters per vehicle entering the downtown area of your city during a weekday morning rush hour from given information on the estimates of automobile, bus, and other traffic. These contexts, while valid, merely give a backdrop to the raw mathematics skills that students are developing within the curriculum. They might be employed in warm up exercises to quickly set a tone of environmental context or be used to build up a basis of tangibility in specific moments anywhere throughout a lesson. To maintain their integrity, these contexts should be drawn from real data as much as possible, and creating overly contrived scenarios should be avoided.The next, middle level that can be employed might take on many appearances. Short reading excerpts from scientific journals, or articles of environmental interest from the local newspaper, might be used to broach a mathematical concept and/or skill set that the class will focus on that day. Video clips of research activities in progress may serve an identical purpose. More significantly, a sequence of word problems might be written to use the numeric data from an environmental contextual source in order to practice skills, and the context referred to continually throughout the tasks that comprise the lesson. This context can also be referred back to as a reflection of "what do these numbers mean?" when the computations and other tasks are completed to provide numeric results.[21]

Providing problem scenarios that require students to creatively apply mathematics skills to find solutions may necessitate the inclusion of more writing exercises. Such writing can effectively be placed in advance of, in parallel with, or following after students' application of math skills (as I mention above in reference to facilitating the teacher's assessment of objectives). Student writing may also fit in at multiple points throughout coursework, with reference to and building from their earlier observations of math skills practice.Expanding the role of organized group discussion at this moderate level will also strengthen students' conceptualization of the connectivity between the mathematics skill set they are practicing and the given environmental context that is being implemented. Such discussion can be used in both small and whole class arrangements, with serious thought toward the objectives of improving students' skill application and decision making relative to which skills are best to apply in a given situation.[22]

The final, high level of context is something that I envision as a project-based series of activities. The overarching structure of such projects (the format and actual skills applied) may rely heavily on which of many environmental subjects are providing the context. The timing of introducing this high level, robust context is very important. It is imperative that the content works with students' prior knowledge as well as with the current curricular priorities. In general, I would make any such project-based course work inclusive of a series of readings, discussions, and mathematics skills application based on real data from the chosen context. A project will be more valid for students' learning if it involves ongoing data collection, communication, and management on the part of students themselves - to the end that they actually discuss and document findings in their own words. [1] [6] Ideally projects can also include high level features such as field studies and guest experts, who can give anecdotal and practical examples of how they use mathematics skills in their fields.The choice of context level may depend more on student preparedness and prior achievement, or more on the content to which the context will be applied. The best implementations of environmental context to a mathematics course will incorporate some composition of all three levels. From the outset of a math course, an understanding should be established, that the students and the teacher are working together toward a valid and meaningful set of educational objectives. As the course progresses, day-to-day lessons can regularly use low and moderate levels of context to relate all of the different, and seemingly disparate, skills and concepts of the course toward some central environmental theme (this is key because a single math curriculum can contain a wide range of concepts and skills). A high-level project structured over these daily activities can provide continuity between subtopics of the given curriculum so that students can see how the many different math skills they learn within a course are actually linked to one another. In this way, the context works symbiotically with content.Before truly bringing any level of environmental contexts to my mathematics instruction, I have to first face one serious reality check. In the Pittsburgh Public Schools, mathematics curricula have come to contain increasingly scripted materials, which math teachers are mandated to follow on a strict basis. As this is also the case for many of my colleagues, the guidelines to adapt lessons that I have developed above require some creative manipulation. The key to this for my purposes will be the direct variation of levels of context to scripted materials[20].

I will use low level contexts to build some validity into the math exercises and activities that my curricula mandate and most thoroughly script. In this way it is possible to remain compliant with district guidelines and still provide the urgent engagement in real application for students. In the instances where the curricula expressly give the teacher options to choose problem sets or sections of the course textbook to draw assignments from, I will use middle level contexts to fortify validity in my students' skill practice and reflective exercises. Middle level contexts can also add a dimension of legitimacy to my teacher created assessments, such as periodic quizzes and take home assignments that contribute significantly to measuring students' independent proficiency at applying math skills. I see the greatest opportunity for high level contexts, again, in multi-part projects that tie together the various skills that sum up to a course.[22]

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