NPTEL
NPTEL ONLINE COURSE
ECOLOGY AND ENVIRONMENT
Sustainability and Case Studies
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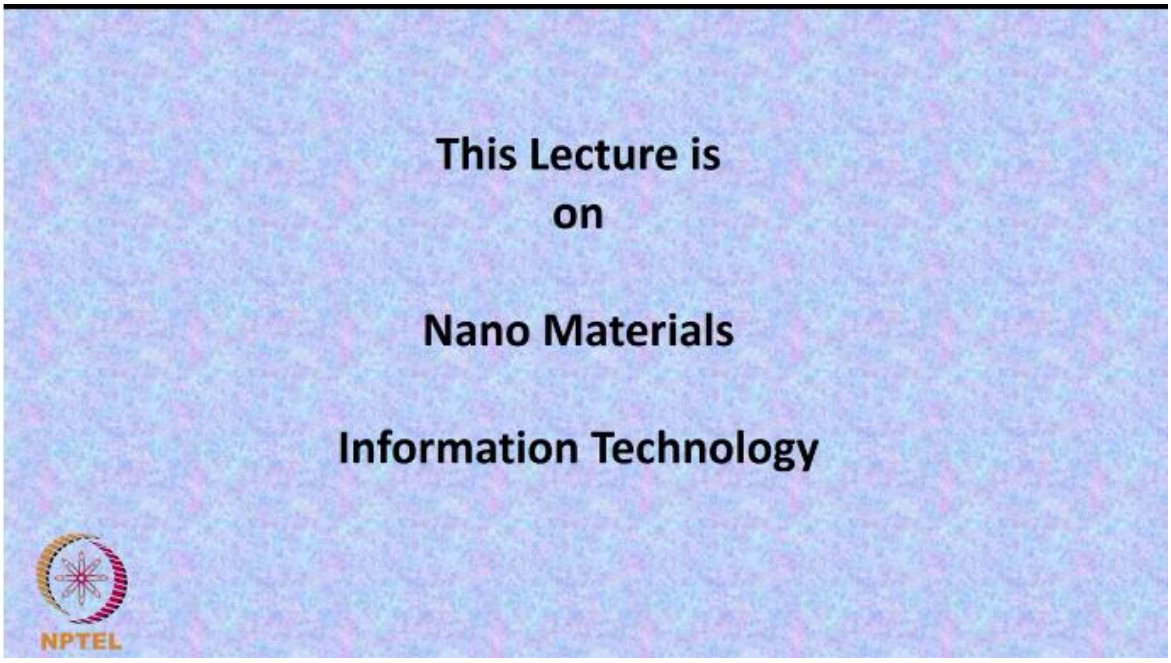
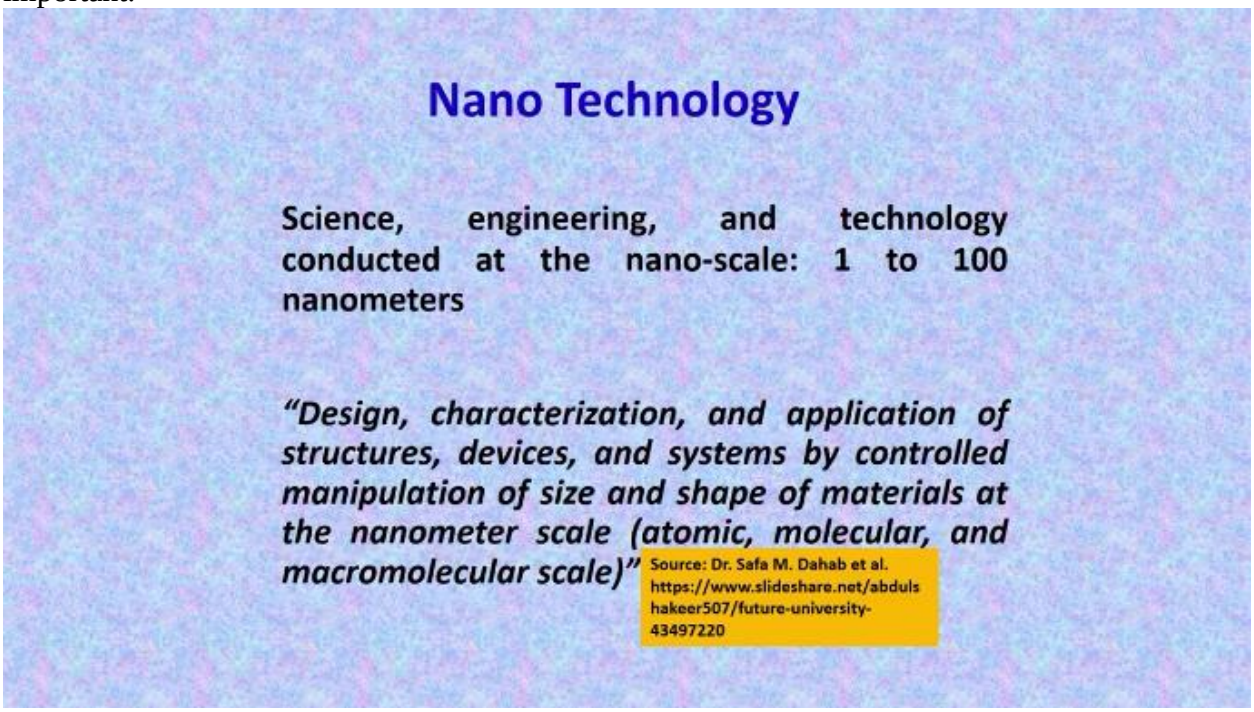
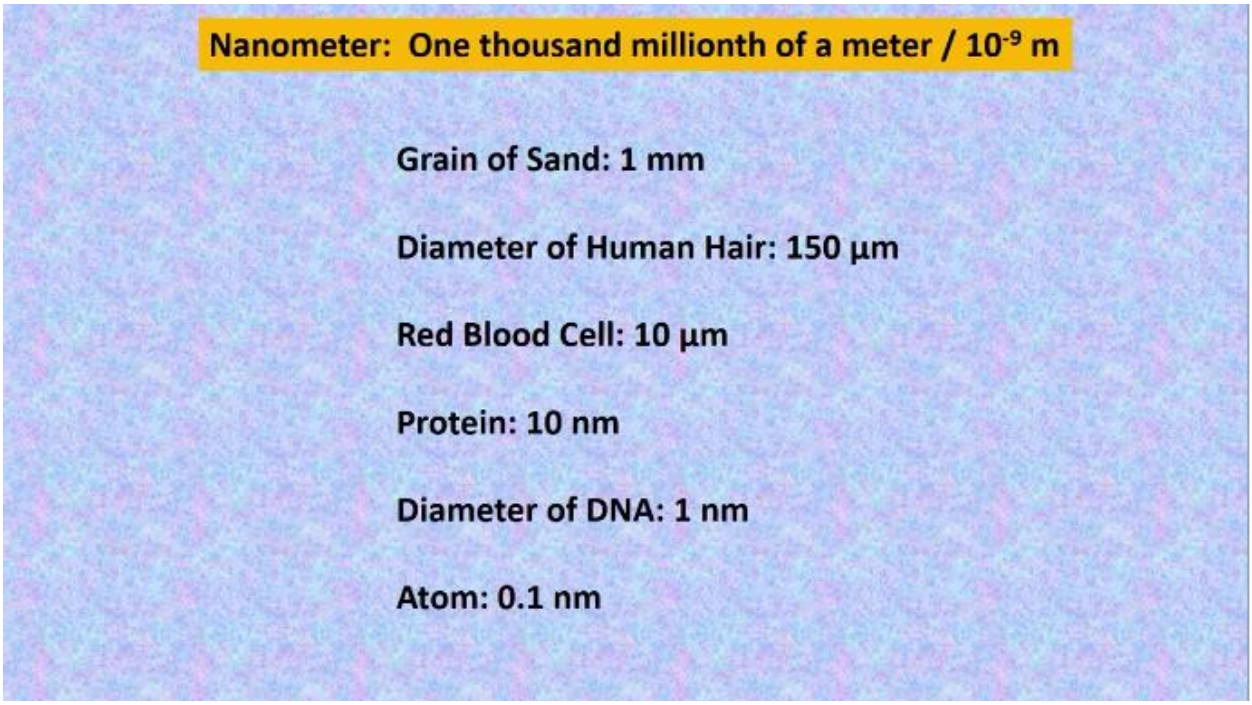
NANOMATERIALS
INFORMATION TECHNOLOGY



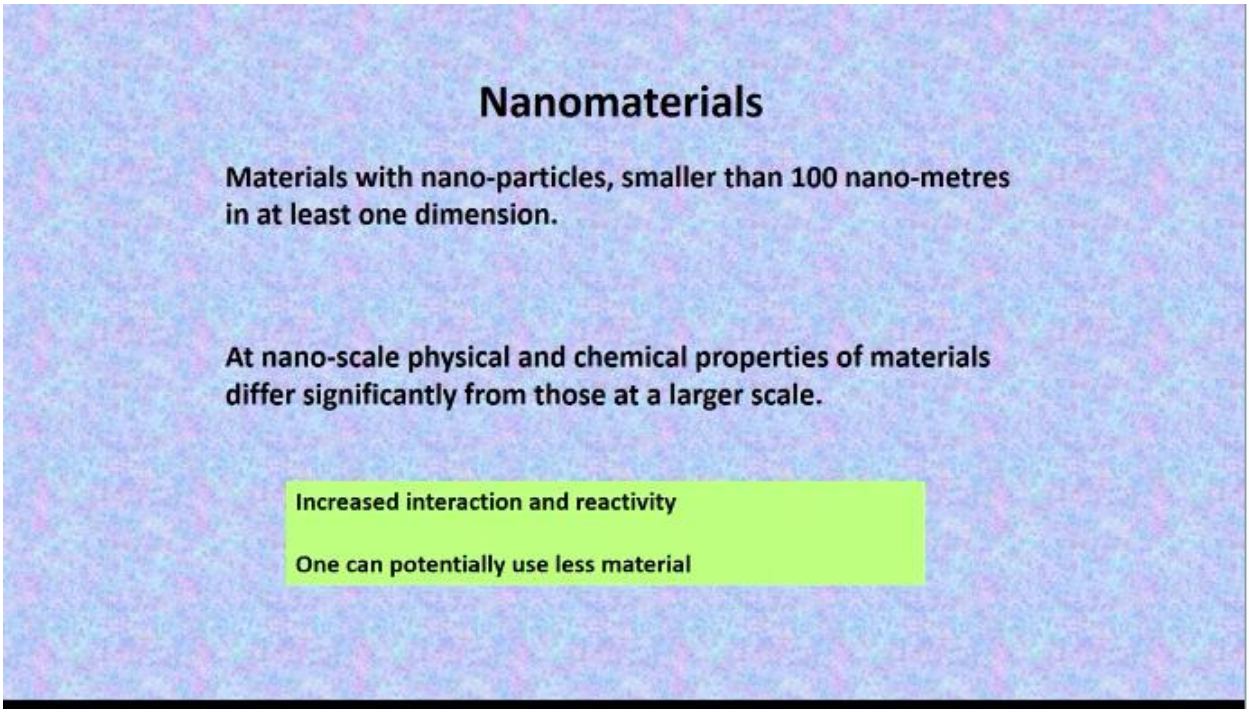
This lecture is on Nano Materials or Nano Technology and Information Technology. As in earlier lectures, we would like to discuss the importance of the effect of technology on environment and ecology and why the principle or concept of sustainable-sustainability becomes important.



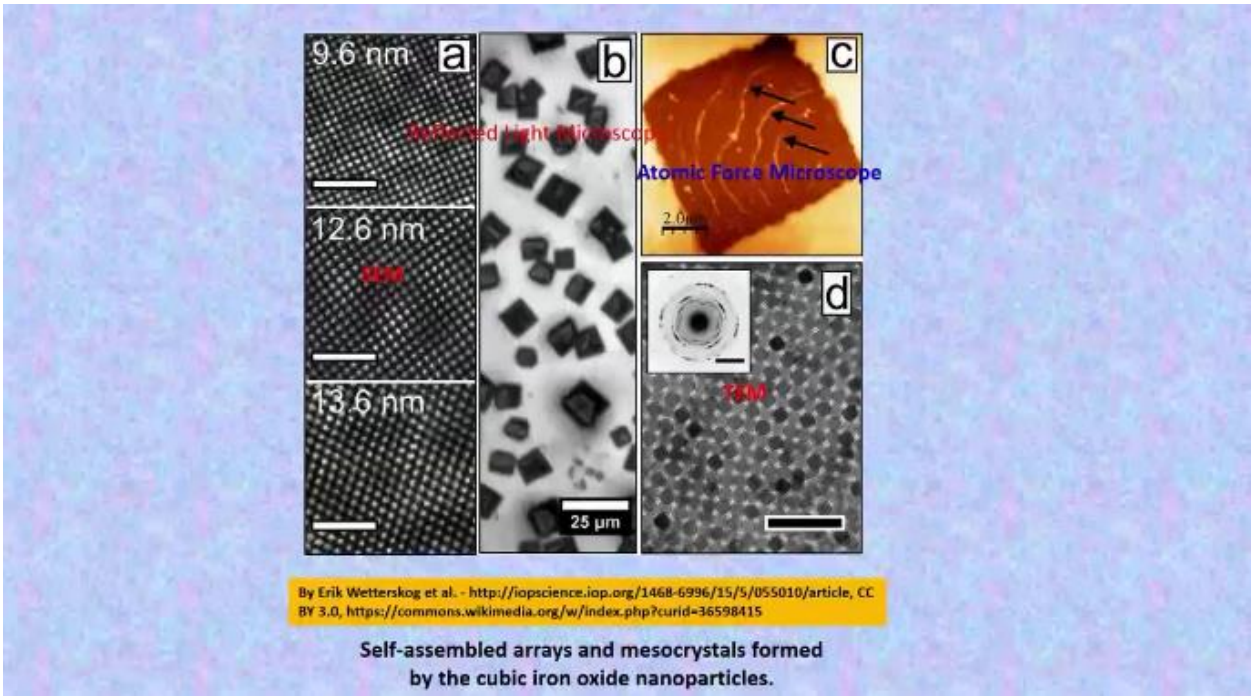
Nanotechnology is our science and engineering and technology conducted at very small scale. So Nanoscales which are 1 to 100 nanometers. It is design, characterization, and application of structures, devices, and systems by controlled manipulation of size and shape of materials at the nanometer scale, that is atomic, molecular, and macromolecular scale.



Let us look at these scales now. A nanometer is one thousand millionth of a meter or 10 to the power of 9 meters, for example, grain of sand it is of the order of 1mm size, diameter of human hair is 150 micrometers, whereas red blood cells are of the size 10 micrometer, proteins are 10 nanometers, diameter of DNA is about 1 nanometer, and atom the size is about 0.1 nanometers. So, this is just to give you an idea about what are the scales that we are talking about when it comes to nanotechnology.



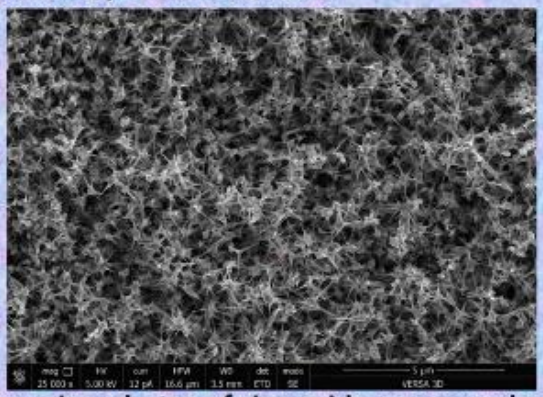
So, nanomaterials are materials with nano-particles which are smaller than 100 nanometers in at least one dimension. The importance of this size is in terms of the properties, at the nanoscale, physical and chemical properties of materials differ very significantly from those at a larger scale. And this is what is made use of in developing technologies at the nanoscale. Because at such smaller scales we will have increased interaction and reactivity of the material. So, one can use less material, potentially use less material to achieve the same goal as you would achieve with materials at larger sizes.



Self-assembled arrays and mesocrystals formed by the cubic iron oxide nanoparticles.

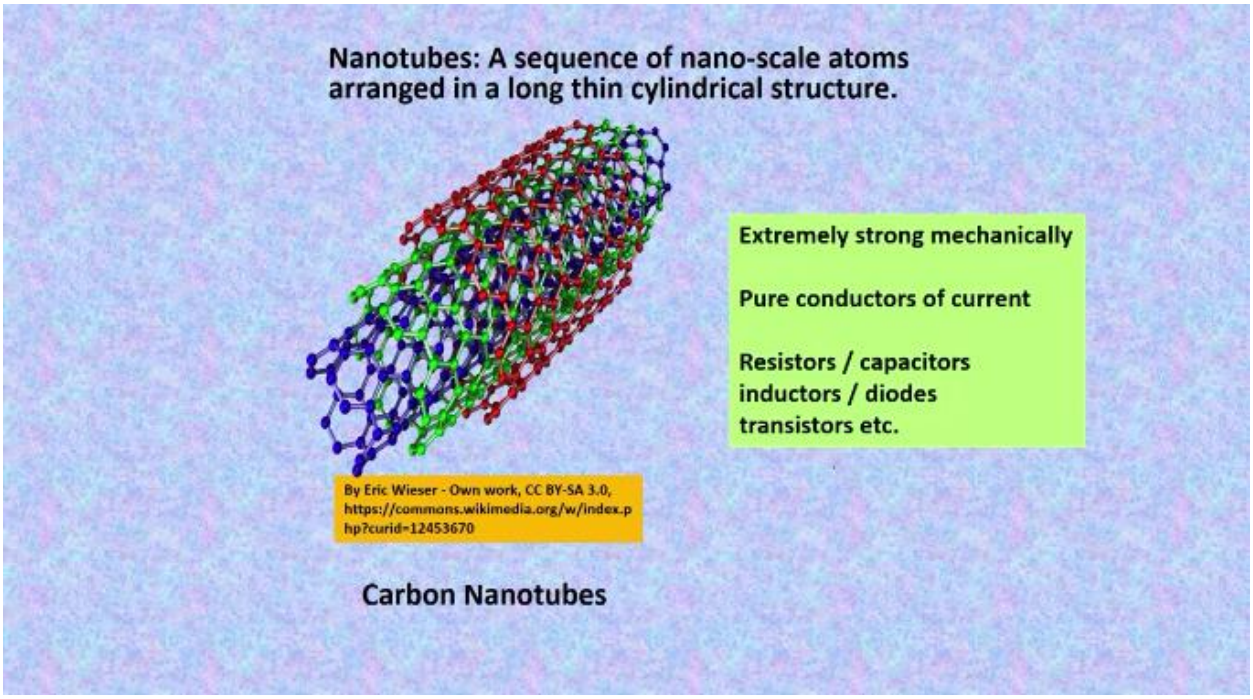
That is the advantage of nano, nanotechnology (audio gap 0:03:32 to 0:03:38) forms. For example crystalline, here we show a self-assembled array and mesocrystal formed by the cubic iron oxide nanoparticles. These are the pictures of scanning electron or pictures taken by scanning electron microscope. This one is taken by reflected light microscopy. This is, this picture here is taken using atomic force, microscope, and these are the TEM pictures, these are nano-crystals.

Nanopowder: An agglomerate of ultrafine particles, *nanoparticles*, or nanoclusters.



The microphotos of zinc oxide nanopowder (ZnO)

We also get nanopowder, which is an agglomerate of ultrafine particles, these are nanoparticles or nanoclusters. Here we show the micro photos of zinc oxide nanopowder ZNO. We get nanotubes which are a sequence of nanoscale atoms arranged in a long thin cylindrical structure, these are a long thin cylindrical structure here.



They are very strong, they are extremely strong mechanically, they are pure conductors of current, and they are very much used in resistors, capacitors, inductors, diodes, transistors, etcetera. So we get these nanomaterials in different forms, we have one-dimensional nanomaterials which are layers and multilayers and thin films, they are very much used in the electronics industry. We also have two-dimensional nanomaterials which are nanowires and nanofibers and then, of course, three-dimensional nanomaterials which are nothing but nanoparticles.

Category	example
One-dimensional	Layers, multi-layers, thin films etc. (Electronics industry)
Two-dimensional	Nanowires and nanofibres
Three-dimensional	Nano-particles

Tools are available for examining and probing atoms and molecule with great precision

In recent years, many tools have become available for examining the properties at nanoscales by probing atoms and molecules with great precession, because of that the nanotechnology has been - is being utilized in many, many situations in engineering.

Applications

Application	Examples
Medicine	Diagnostics, Drug delivery etc.
Information and communication	Semiconductor devices Quantum computers
Heavy Industry	Aerospace, Construction Vehicles
Consumer goods	Textiles, Cosmetics etc.

Environmental Engineering:
- Carbon Capture
- Sensors
- Decontamination
- Wastewater Treatment

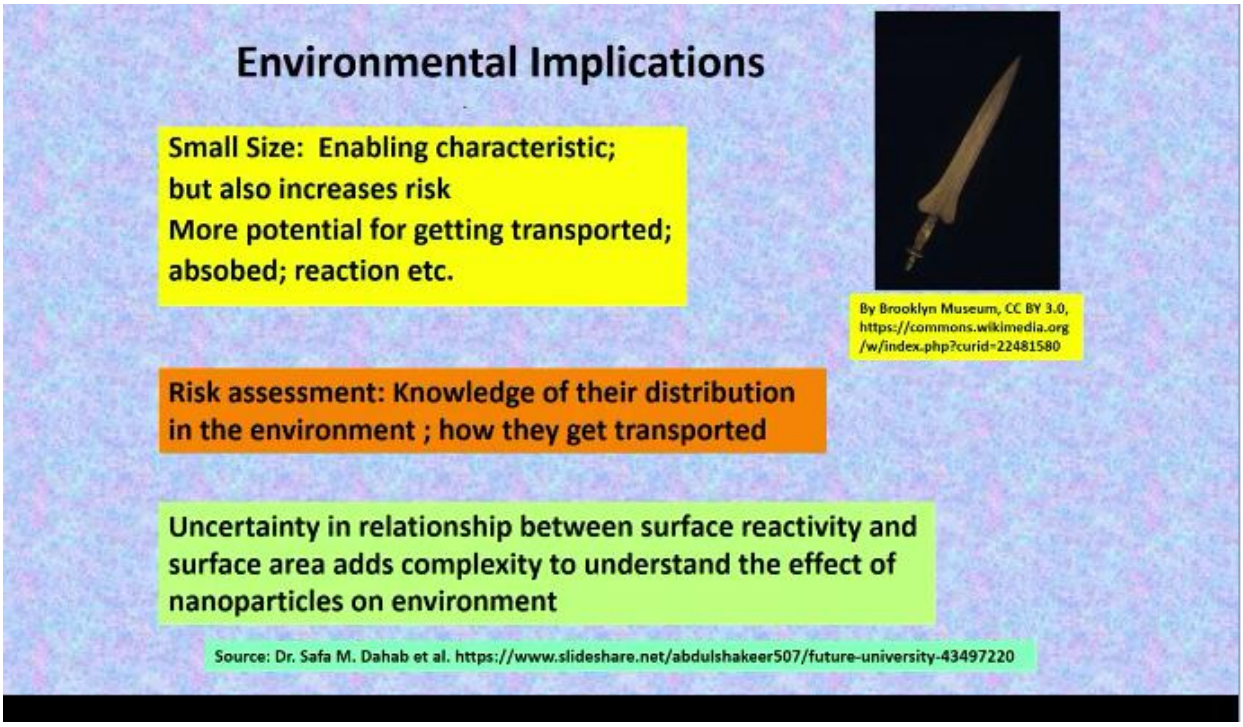
Detection of metals; biological agents
Nano biocides
Biofilm removal
Nanofiltration

Source: Dr. Safa M. Dahab et al. https://www.slideshare.net/abdulshakeer507/future-university-43497220

As I was mentioning, there are varied applications in medicine, nanotechnology can be used for diagnostics, drug delivery, etcetera. In IT or information and communication, they are used for

making semiconductor devices, quantum computers, they are also useful in heavy industries such as aerospace, construction vehicles etcetera. And they find application in consumer goods like textiles, cosmetics etcetera.

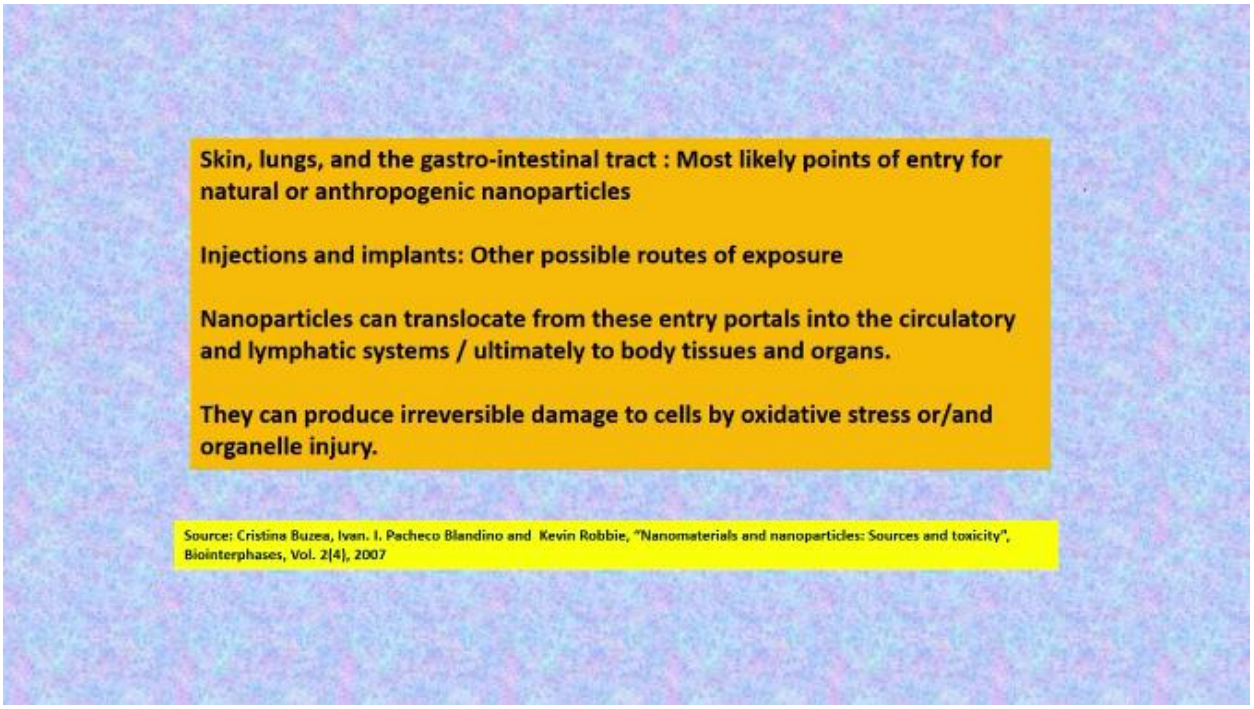
In environmental engineering, nanotechnology finds a lot of applications. Nanotechnology can be used for carbon capture, and reduce the GHG emissions greenhouse gas emissions, it can be used for making sensors which can detect the water quality or wastewater quality. Nanotechnology can be used for decontamination of oil spills, can be used in wastewater treatment, nanosensors can be used for detecting metals and biological agents. Nanotechnology can be used for making biocides, removal of biofilm and lot of applications are coming up these days, utilizing nanotechnology for water purification which is very important in these days when we are finding a lot of contaminants in water, and then we need to remove them. So, nanofiltration is a big thing in terms of water purification.



Now, what are the implications, environmental implications, in fact, nanotechnology is like a double edge knife that I am showing here. The small size enables, I mean it is an enabling characteristic because it is increasing reactivity as I mentioned earlier. But the small size also increases the risk. There is more potential for material with such small scales, nanoscale or nanoparticles they can get transported much more easily, and they can get absorbed. We are utilizing the characteristics of higher reactivity of nanoparticles for developing the technology, the same thing can work against us, when these nanoparticles get into the environment. They may react with the environment in a way that we do not want, so it is a double-edged knife. So, we need to do the risk assessment of these nanoparticles getting into our environment. We need to have knowledge of their distribution, how they get transported, I mean nanoparticles which get introduced into the atmosphere or into the environment at one particular location, they do not stay there, they have mobility, in fact, they have increased mobility, they move from one location

to another location, they get transported. So, we need to have a knowledge on how they get transported, and as they are getting transported, how they are reacting with the environment. That knowledge we need to have to do the risk assessment of this nanotechnology.

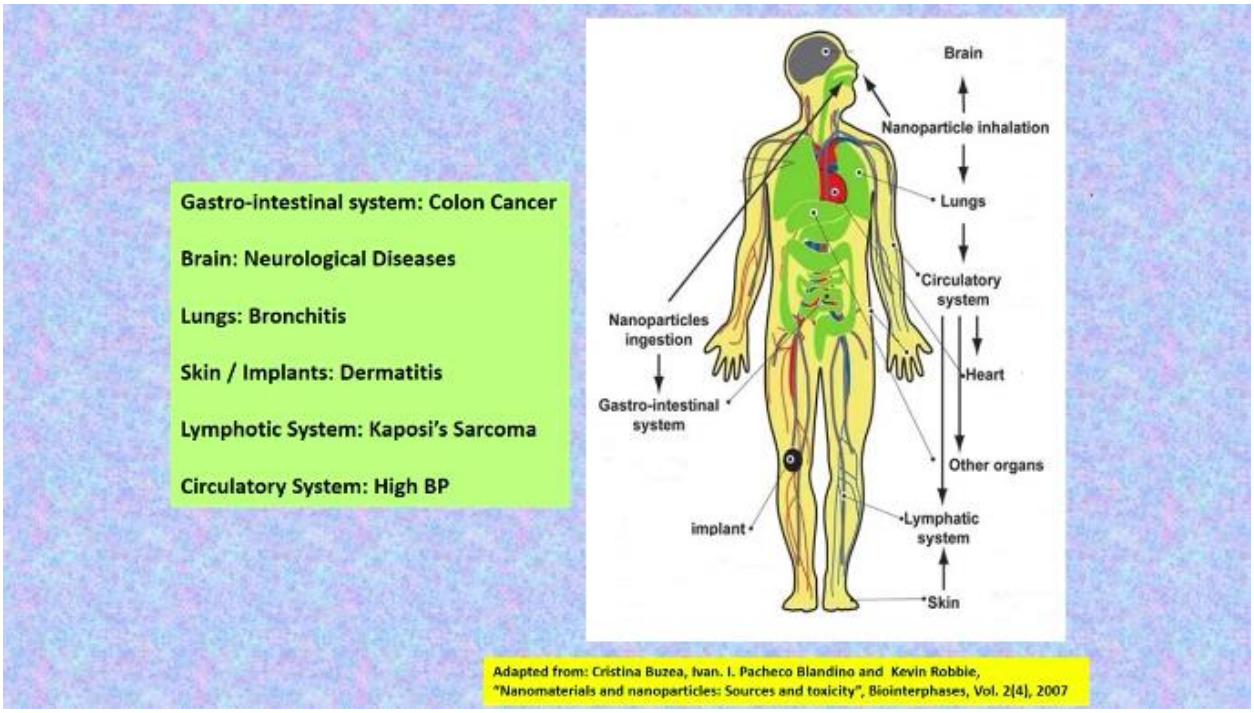
The main problem is, there is a lot of uncertainty. We do not know much, there is an uncertainty in the relationship between surface reactivity and surface area, that itself is not completely understood. So, since it is not completely understood, it adds complexity in terms of assessing the risk, in terms of understanding the effect of nanoparticles on the environment.



Lot of work is being carried out in this area. It has been found that skin, lungs, and gastrointestinal tracts, they are the most likely points of entry for natural and anthropogenic nanoparticles into the bodies of animals and humans. Of course, they may get injected, or they may get implanted, they are the other possible routes of exposure.

Nanoparticles can translocate from these entry points or entry portals into the circulatory and lymphatic systems and eventually or ultimately, they may find their way to body tissues and organs, and that may have a detrimental effect.

It is suspected that they can produce irreversible damage to cells by oxidative stress and or organelle injury. Here we show a picture, which I have taken from a paper published by Cristina Buzea and others in 2007.

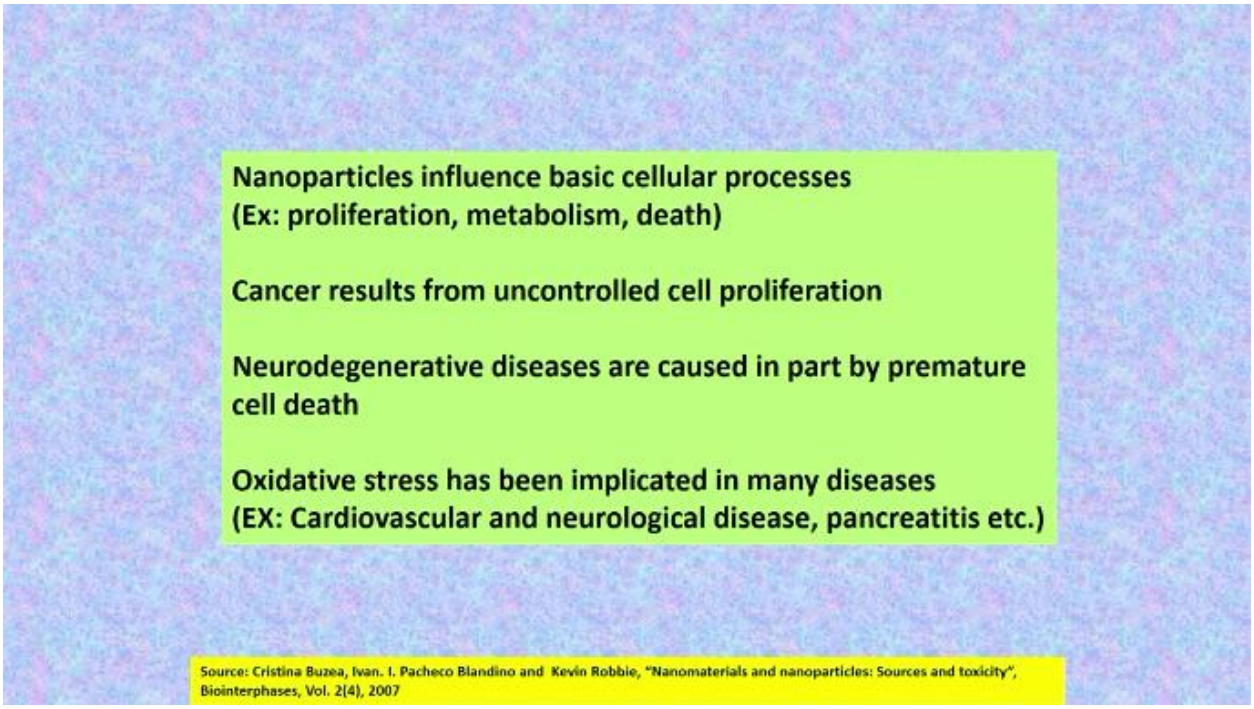


It shows the entry points for nanoparticles into the human body like nanoparticles can get ingested here, or nanoparticles can get inhaled, or you may have orthopedic implants or they can enter through the skin. And once they enter into the body, they can get into the lymphatic system or from the lungs, they can get into the circulatory system, then they can go to the heart, and other organs and then they can get into gastro-intestinal systems as they are ingested.

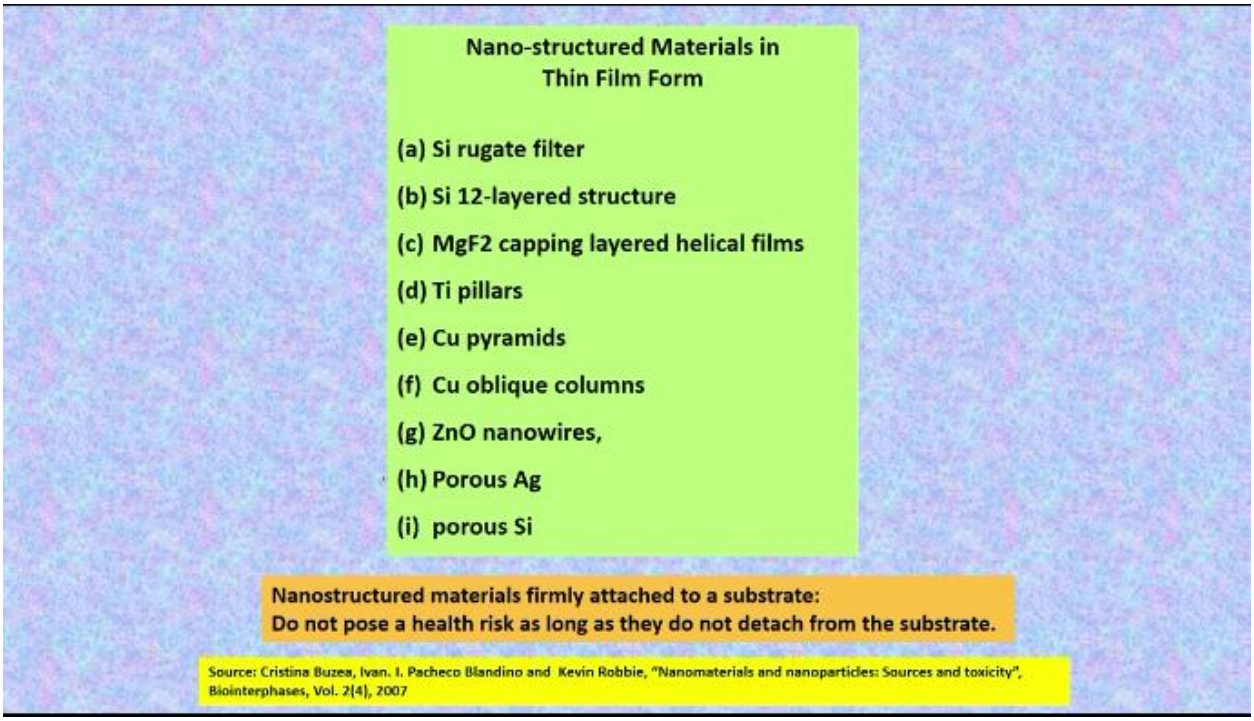
They find their way to all parts of the body, and what are the effects? If they get in large quantities in the gastrointestinal system, they can cause colon cancer, can cause when they get to the brain they may cause neurological diseases like Parkinson's, Alzheimer's, dementia. When they get to the lungs, they may cause bronchitis and other problems.

If they are there through skin or implants, they may result in dermatitis. In lymphotic system, they cause Kaposi's sarcoma, and of course, if they get into the circulatory system, they can cause high blood pressure and heart diseases and may lead to death. Basically nanoparticles influence cellular processes, examples like proliferation, metabolism, and death, and as you know, cancer can result from uncontrolled cell proliferation.

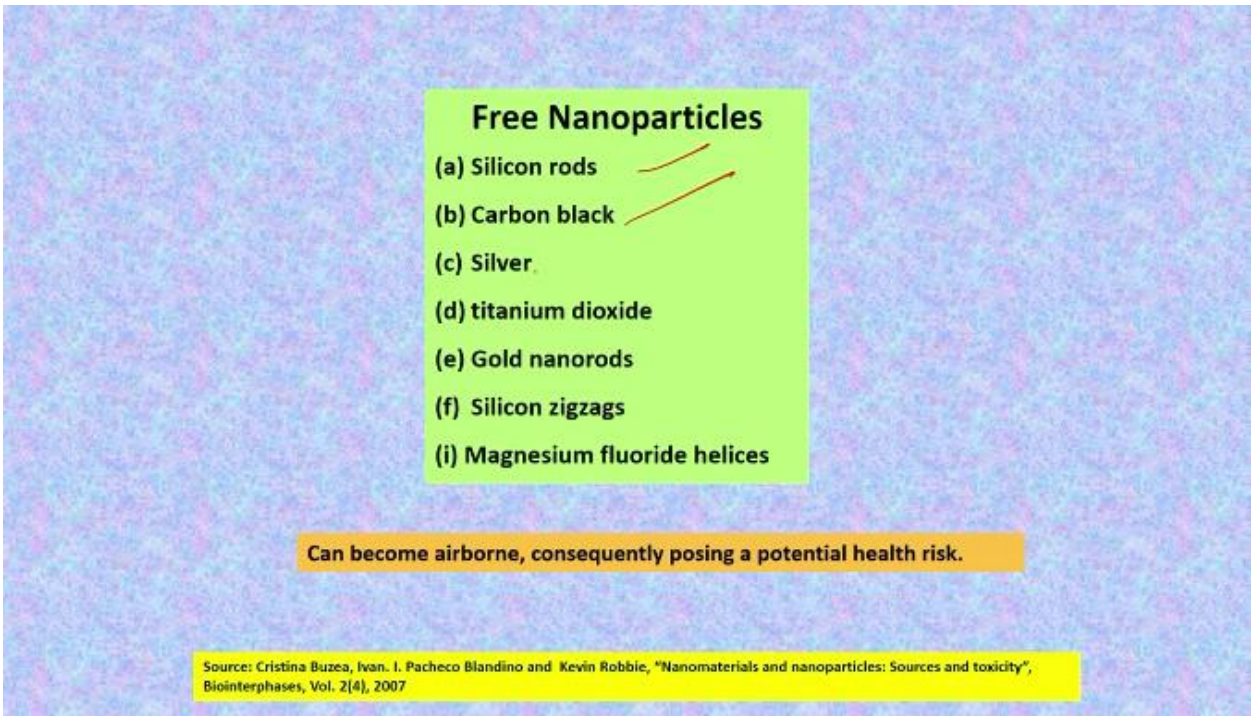
Neurodegenerative diseases are caused in part by premature cell death, it has been known that oxidative stress can cause many diseases like cardiovascular and neurological diseases, pancreatitis etcetera.



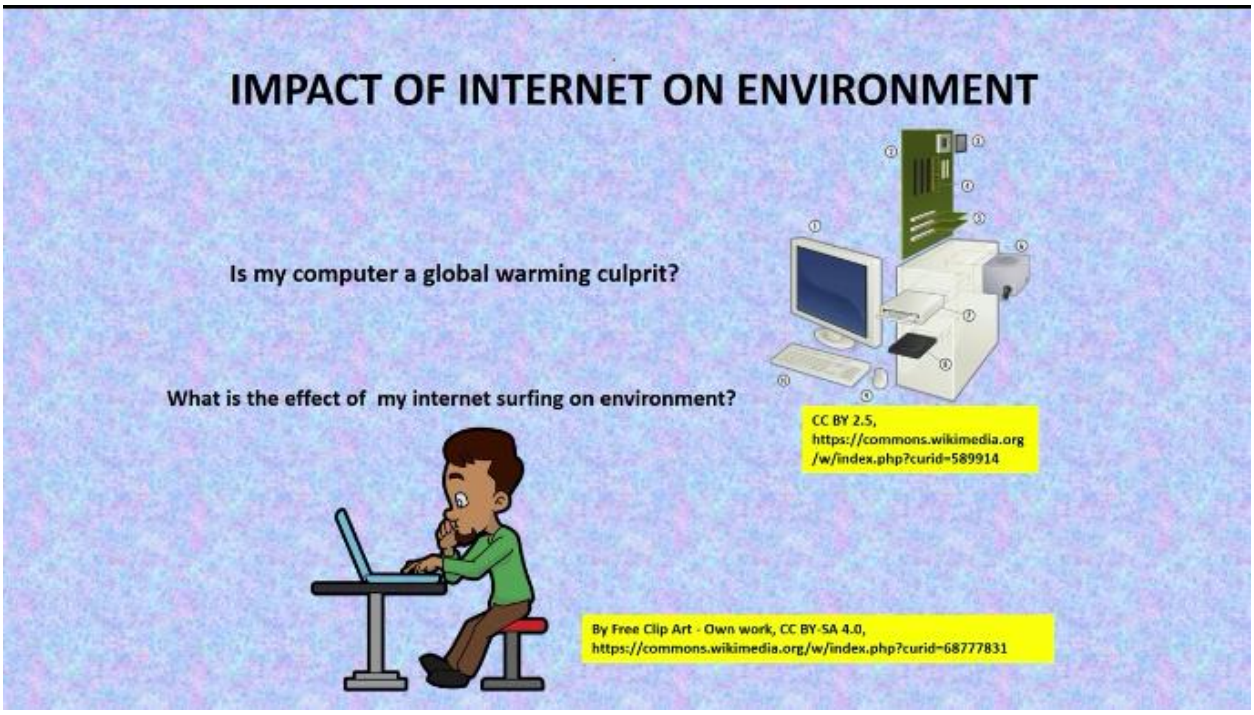
So, we need to be careful when we introduce this nanotechnology. We need to assess the risk of having some nanotechnology risk, in terms of its effect on the environment, its effect on ecology and ultimately its effect on human health. So, to reduce the impact, if we prevent the entry of this nanoparticles into the environment, then we can reduce the impact.



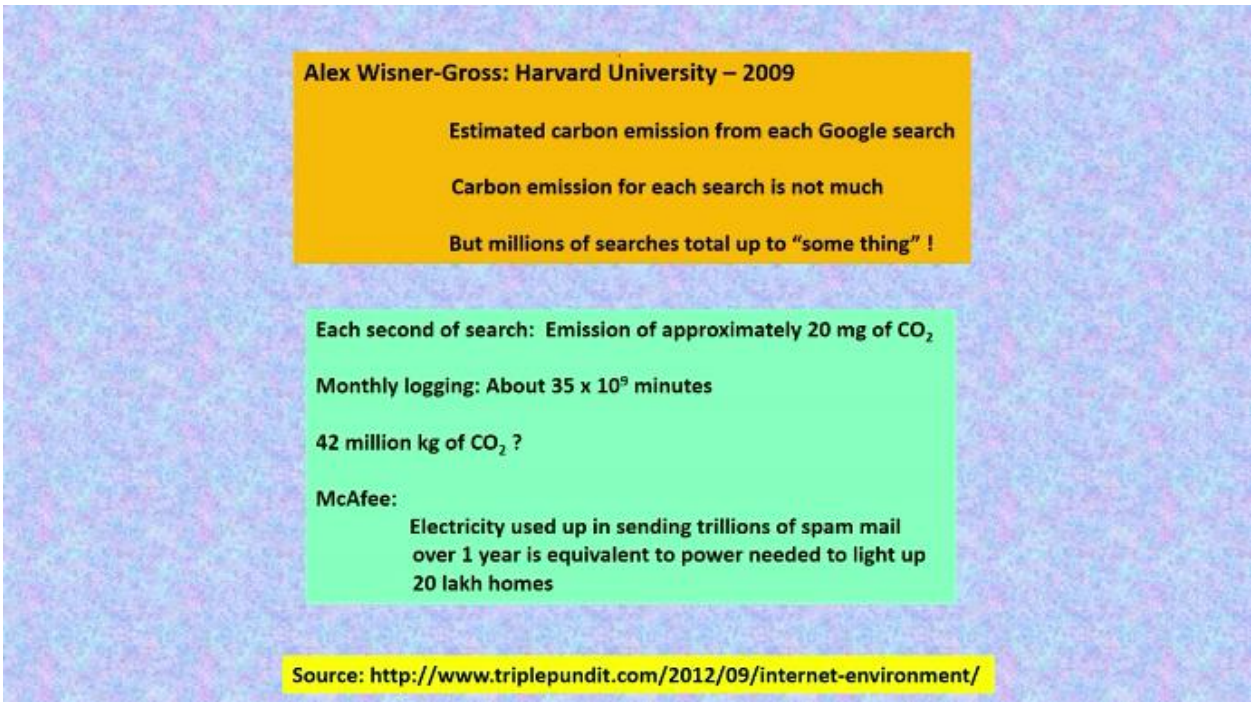
For example, if we utilize nanostructured materials in thin film form then these nanostructure materials are firmly attached to a substrate, they do not pose a health risk as long as they do not detach from the substrate. Like some examples of this thin film form are silicon rugate filter, titanium pillars, copper pyramids, zinc oxide nanowires, porous silver, porous Ag, porous silicon, these are some of the nanostructured materials in thin film form.



Whereas if we are utilizing free nanoparticles they can become airborne very easily, and as a result, they pose a potential health risk. Like free nanoparticles are silicon rods, carbon blacks, silver, titanium dioxide, silicon zigzags etcetera. So, if you are using these things in our technology, we need to do some risk assessment, and then see how much or what is the potential for them to become airborne and consequently pose a potential health risk.

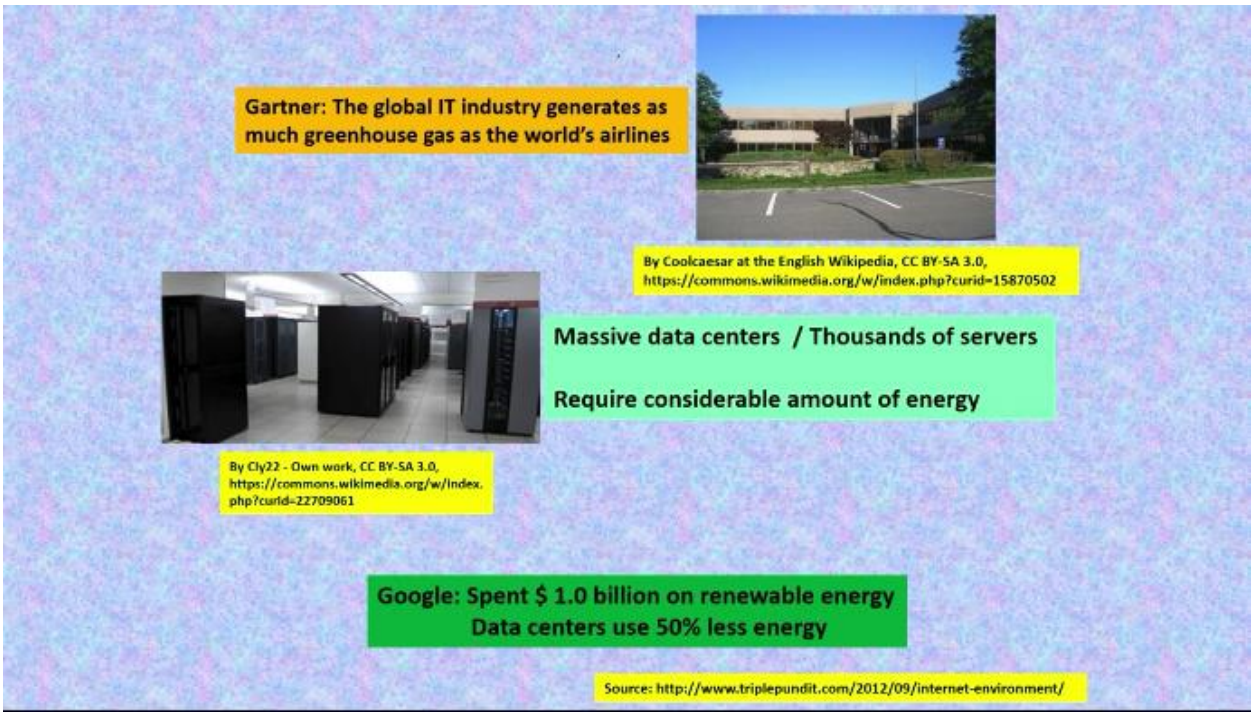


Next, I would like to discuss the internet and the environment. Or what is the impact of the internet on environment? I ask this question because we use these computers so much these days, so ubiquitous. I ask this question, is my computer a global warming culprit? Because of these computers, how much greenhouse gases or the emission of greenhouse gases has increased? I ask a question, what is the effect of my internet surfing on the environment? All of us do so much of internet surfing, all of us use the internet so much, how is it affecting the environment?

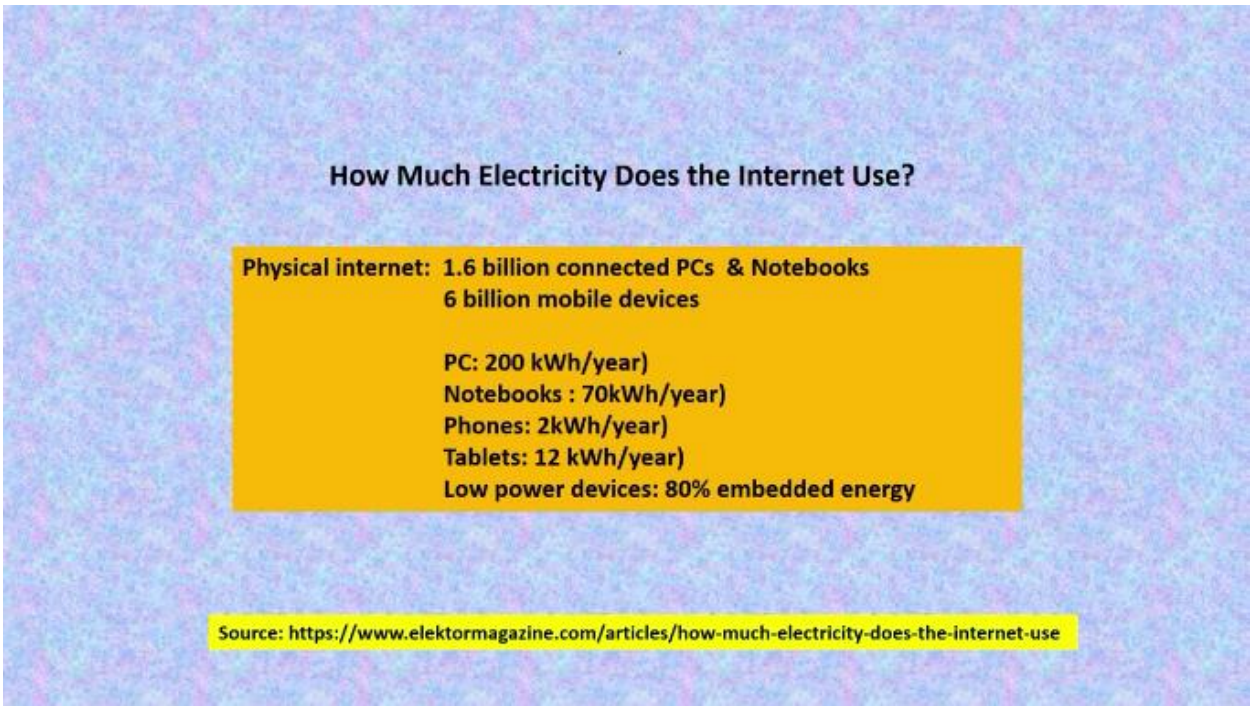


Alex Wisner-Gross of Harvard University in 2009, he has estimated that carbon emission from each Google risk, Google search, for each search the carbon emission is not very much but millions of searches, we are doing millions and billions of searches, they all total up to something. Each second of search the emission of approximately 20 milligrams of CO_2, and it is estimated that monthly login on the internet is about 35 into 10 to the power of 9 minutes, that means 42 million Kg of CO_2 is getting emitted, that is substantial.

McAfee has found that electricity used up in sending trillions of spam mail over one year, spam mail over one year is equivalent to the power needed to light up 20 lakh homes; 2 million homes. So, you can see what is the effect that the internet is having on the environment.



The global IT industry generates as much greenhouse gas as the world's airlines. Massive datacenters and thousands of servers which are required for running this internet, they require a considerable amount of energy. In fact, many of this internet giants are sensitive to this, and they do, they take actions in terms of saving the energy.



Google is supposed to have spent one billion dollars on renewable energy, and they also design and operate the datacenters in such a way that those centers use 50% less energy. We ask a question; how much electricity does the internet use? For example, the physical internet, 1.6 billion connected PCs and notebooks are there, 6 billion mobile devices. Now a PC uses 200 kilowatt-hours per year, notebooks 70 kilowatt-hours per year, phones 25 watt-hours and tablets 12 kilowatt-hours. So, low power devices have 80% embedded energy. Now, this is just to give you an idea on what is the power requirement, how much of power these devices are utilizing, and then can we do something about it, can we save some power in this aspect, like data centers, they use 1 to 2% of the worlds energy.

Data Centers: 1 to 2% of worlds energy (Eric Masnet, NW University)

Moving locally hosted services to large centers: May reduce energy cost by 87%

System Thinking: Consumes electricity
but net environmental impact can be positive !

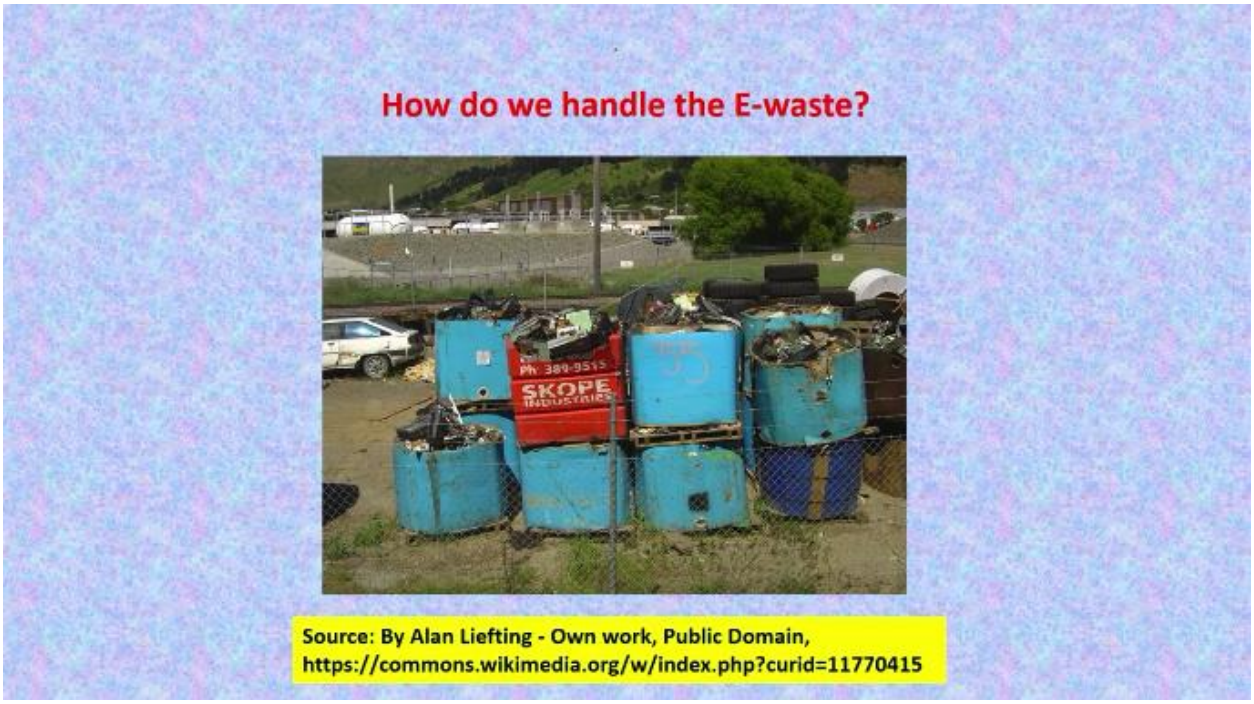
Ex: Downloading music is 40 to 80% less harmful compared to buying a CD

Smart Parking Lots

Public Domain, https://commons.wikimedia.org/w/index.php?curid=623829

Source: https://www.elektormagazine.com/articles/how-much-electricity-does-the-internet-use

So, if we move locally hosted services to large data centers, it is estimated that we may reduce energy cost by the internet by 87%. Of course, when we say these things we also need to think about what are the positive aspects of the internet or how the internet can be used positively to increase the sustainability. So, we need to have some systems thinking. Yes, the internet consumes electricity, but the use of the internet may have a net environmental impact on the positive side. Somebody has given this example of - downloading music is 40 to 80% less harmful as compared to buying a CD, or we can use internet for operating parking lots in a smart way and then save the cost from increased fuel usage. So, when we talk about these effects, we have to think in a systems way that is what is the, in overall what is the impact it is having.



But then we also have to be sensitive about what we are doing with this E-waste, this internet, and IT industry, use of computers eventually generates a lot of electronic waste. Now handling the electronic waste is not the same as handling other type of waste, for example, the food waste that comes out of our houses, that is much easier to handle than handling this E-waste. So, what are we doing with this E-waste? Is it that, it is out of our premises and it is out of our mind. Where are we sending this, what are we doing with it?

So, these are some of the questions we need to think about when we are utilizing the internet.

Thank you.