Federation of Earth Science Information Partners

Sustainability: A Cleantech Industry Perspective

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Picture - Courtesy of NASA

Disclaimer: This white paper presents a synthesis of opinions from some of the industry leaders in Cleantech arena and results of discussions with them, and does not constitute direct endorsements by their respective institutions.

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Executive Summary

This report addresses environmental sustainability in the context of energy-water-climate nexus. The objective is to provide a synthesis of opinions from selected knowledge experts and practitioners in the cleantech industry, capture key challenges and best practices from various perspectives, and provide a commentary on energy and environmental factors critical to sustainable economic growth.

Earth's climate is changing at an alarming rate as evidenced by a multitude of observational trends. These include increase in average global temperatures, melting of ice in the Polar Regions, rapidly receding glaciers, changing precipitation trends impacting agriculture, marked decline in ecosystem and biodiversity, and increased frequency and intensity of extreme weather/climate events including droughts, wildfires, tornadoes, hurricanes, and floods.

At the same time, the world population is rising (expected to grow from 7.2 billion in 2013 to 9.6 billion by 2050), and economic growth in developing countries is accelerating – all competing for diminishing natural resources. These three factors – rising population, economic growth, and climate change – will have profound impacts on availability of fresh water and clean energy, agriculture and food production, public health, survival of ecosystem and biodiversity, and infrastructure resilience to extreme events.

Fossil fuels made the industrial revolution possible, but the byproduct was an increase in the amount of green-house gases in the atmosphere. The atmospheric content of CO2, the primary contributor, has increased steadily from 316 ppm in 1958, and reached 400 ppm mark in May 2013.

Most scientists agree that this anthropogenic activity is the primary cause of the observed climate changes, and anticipate more impacts in the future. In spite of the efforts spanning for over 20 years by the government leaders worldwide, there is no international agreement in place to control carbon emissions. Stopping CO2 at 450 ppm, considered to be relatively "safe" target, is at risk.

The world stands at very difficult crossroads with a challenge – how do nations continue much-needed economic growth, ensure energy security, and enable improved quality of life, while limiting environmental degradation to a manageable level before it reaches a damaging point-of-no-return.

To address this challenge, a new "sustainability megatrend" has emerged and many corporations and startups, leading this movement, are beginning to find solutions that would facilitate environmentally responsible and sustainable growth. Massive opportunity exists, which started as eco-efficiency, but later turned into how people thought in a systemic way of achieving low costs and delivering high value products and services, which improve both the top line (revenues) and the bottom line (profits).

Sustainability, from environment standpoint, is being addressed on three frontiers:

- Resource availability (energy and water supply) for consumption and economic growth while protecting the environment and ecosystem.
- Conservation and efficient use of these limited resources (energy and water demand).
- Building infrastructure resilience to natural disasters and extreme weather/climate events.

Some early achievements of this megatrend include:

- Solar and wind power prices beginning to reach parity with fossil fuels in selected regions.
- Eco-friendly products and services increasing profits as well as reducing carbon footprint.
- Big data and IT solutions enabling improved energy and water usage, more efficient business operations, and facilitating information for building resilience.
- Emergence of new business models with sustainability as a core component.

Water and energy are highly interconnected and both are in limited supply. Because of this, efficiency, conservation, waste reduction, and making better use of resources are paramount themes emerging in "save the planet and ensure sustainable economic growth" discussions.

Big data, Cloud computing, and IT are radically changing the way corporations are approaching solutions to both energy and efficiency problems. Networks and data centers, supporting massive exponential data growth, are becoming more efficient and sustainable. Entrepreneurs are asking the question - how can we make this data meaningful? How do we connect to each other through social networking and mobile technologies, share ideas and useful information, and enable people helping other people worldwide? Social networking has become an important driver of the sustainability megatrend.

Thus, although Cleantech started out as a B2B activity, it is now becoming more consumers focused unlocking other channels such as behavioral science and data from social networking platforms such as Facebook and Twitter. Silicon Valley, with its strength in information and communications technologies (ICT), is taking an active role in bringing this innovation to Cleantech. Crowdsourcing has emerged as a new model for raising seed money for innovative cleantech startups– thousands of individuals are voting for what is needed by making small financial contributions for worthy projects.

Globally, two distinct points of view continue to persist - "environmental focus with a sense of urgency to stop further degradation", and "economic stability and growth first, everything else secondary". There is a concern that availability of abundant shale natural gas with a promise to provide energy independence, and cleaner than coal but still carbon based, may slow down renewable fuels and "green" raw material, chemicals, and products growth.

Indeed, after a steady rise since 2004, total global investment in clean energy saw a decline in 2012, but it remains strong, and appears to have stabilized. A similar trend has been evident in cleantech venture financing, which saw a boom from 2009 to 2011, and then a decline in 2012.

Now a renaissance appears to be on the horizon - storage, efficiency, social media, and IT are being viewed as the top domains for cleantech innovation in addition to the search for low price clean energy.

Global sustainability issues are paramount, and there is no silver bullet. The energy mix in 2050 may still have a large proportion from fossil fuels if major changes are not undertaken. This would challenge controlling of GHG emissions to manageable levels in coming decades. Improvements are needed in all the areas that could make a positive impact to ensure sustainability – these include technology innovation, business practices, and government regulations. Numerous opportunities exist for public-private partnerships to make this happen.

1. Introduction

The purpose of this report is to provide a synthesis of opinions, ideas, and assessments about sustainability and resilience in the context of energy-water nexus and climate change from a variety of cleantech industry thought leaders from large corporations, investor community, and start-ups, along with author's own viewpoints and commentary.

The discussion here revolves around major current issues and challenges, best practices in addressing them with cleantech solutions as well as new business models, and what lies ahead. This report is not meant to provide an exhaustive survey, but the objective is to capture a snapshot of some leading work and valuable insights.

2. Sustainability Challenge and Megatrend

2.1 Climate Change

Earth's climate is changing at an alarming rate as evidenced by the changing observed temperature and precipitation trends, melting of ice in the polar regions and in rapidly receding glaciers, marked decline in ecosystem and biodiversity, and increased frequency and intensity of extreme weather/climate events including droughts, wildfires, tornadoes, hurricanes, and floods. Rising damages over the last decade from such extreme events worldwide, and most recently from the superstorm Sandy in the US Northeast, have raised the bar and created an urgency for action.

While short term climate variability exists as a natural phenomenon, most scientists agree that the changes in the long term "average" climate conditions or trend are being caused by the increase of CO2 and other GHG emissions in the atmosphere (also see AGU statement 2013). Fossil fuels which drove industrial revolution and economic growth also produced emissions that are taxing the environment (Figure 1).

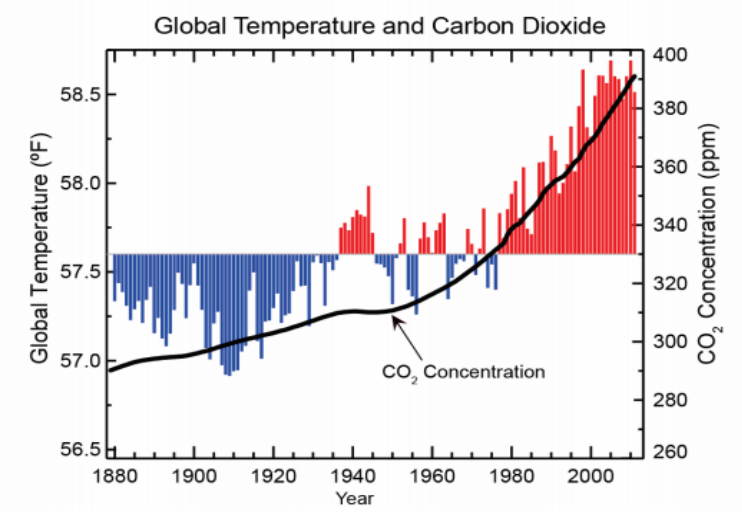

Figure 1. Rise in global temperatures and CO2 concentration
(Source: US National Climate assessment – Draft for Comments, January 2013).

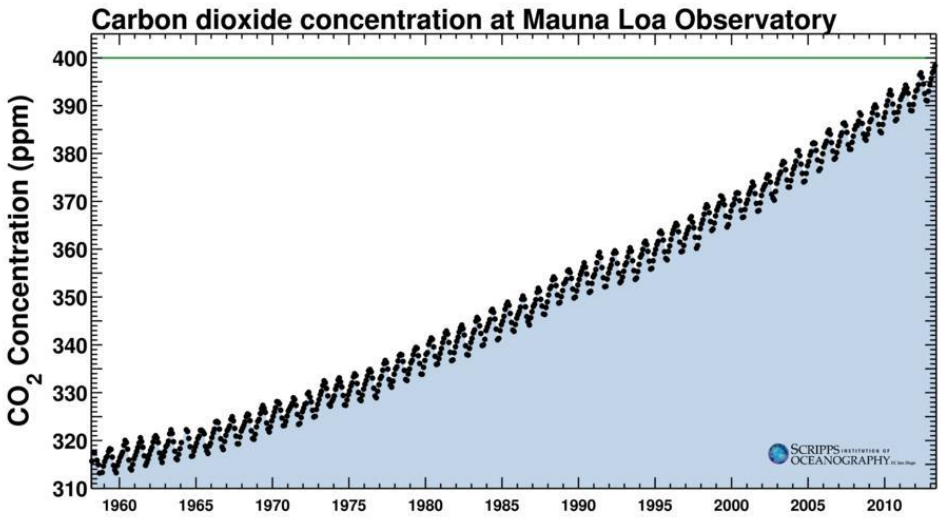

Figure 2. The Keeling Curve (May 2013)

The atmospheric content of CO2, the primary greenhouse gas that has been accurately tracked since 1958 (known as the Keeling Curve), has continued to rise and the rate-of-change is accelerating. On May 6, 2013, CO2 content crossed 400 ppm mark (Figure 2).

Efforts to gain consensus in the United Nations Framework Convention on Climate Change (UNFCCC) to arrive at international regulations have been challenging. We may already be past the point of arresting CO2 at 450 ppm, which was considered a reasonable and desirable target in previous international negotiations if we are to keep the probabilities of global temperature increase to 2 degrees in our favor.

It has been argued that even 2 degrees rise is too high, and could lead to a high cost. Moreover, some recent climate models indicate that 450 ppm of CO2 could lead to even higher than 2 degrees rise in global temperature. As it stands, CO2 in the atmosphere will continue to rise if we don't make adjustments fast enough.

2.2 Economic, Social, and Political Considerations

Two major trends are expected to drive sustainability requirements during the next several decades. First, the population is rising. According to a recent United Nations report published in June 13, 2013, the world population, 7.2 billion today, is expected to increase by 1 billion over the next 12 years, and reach 9.6 billion by 2050.

Second, rapid global economic growth is in progress, notably in China, India, Brazil, Russia, and Indonesia, and the pace is likely to continue as developing economies have access to technology and resources that were available only to the developed countries during the industrial revolution.

These global socioeconomic changes combined with climate change will have direct or indirect impact on fresh water availability, agriculture, energy supply and demand, public health, ecosystem and biodiversity – the major societal impact areas (Figure 3).

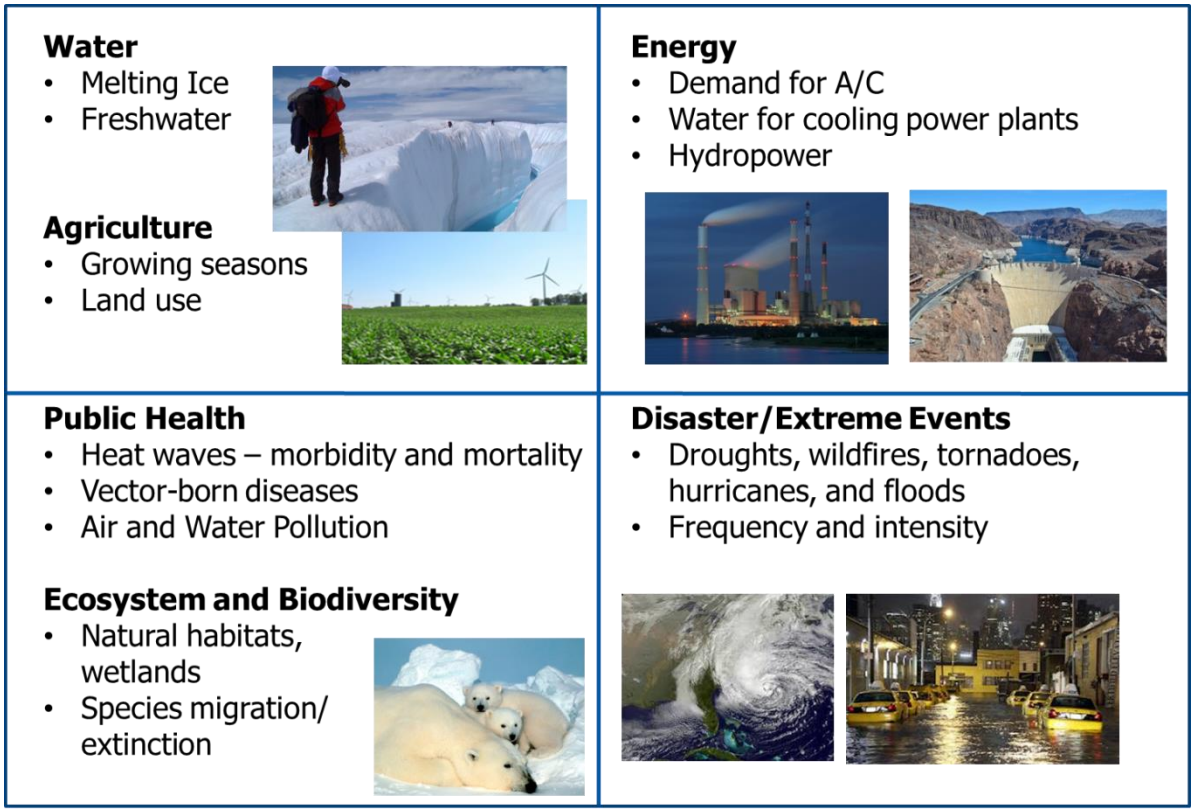

Figure 3. The societal impact areas from global changes (Source: GEOSS, USGCRP)

The Intergovernmental Panel on Climate Change (IPCC) published a report on potential global impacts (the fourth assessment report - AR4) in 2007, which raised major sustainability concerns and need for action. Since then, the IPCC has been working diligently to provide an update with further scientific inputs; the next report (the fifth assessment report - AR5) is expected to be released in 2014.

The third US National Climate Assessment (NCA) (draft for public comments issued in January 2013) has taken a comprehensive look at these impacts in the US. For observed trends, the most obvious are increases in extreme precipitation and decreases in cold waves. Heat waves have increased, but not yet to the levels of the 1930s Dust Bowl era. Hurricanes have increased over the last 20 years compared to the previous 20 years, although high levels appear to have occurred earlier in the century. There is no observed trend in tornadoes, as far as the climate scientists can tell from non-ideal data.

The increase in frequency and intensity of extreme weather and climate events has resulted in rising human, economic and property losses during the last decade.

Regarding predictions and climate change projections, Ken Kunkel, a lead author for the 2013 US National Climate Assessment noted that "the science community has confidence in projections of increases in extreme precipitation and heat waves, decreases in cold waves, increases in the intensity of the most extreme hurricanes, and increases in drought in the US southwest. We do not think we can make confident projections of tornadoes [today]."

With stakes this high, the diversity of economic and social conditions around the globe, and continuing security concerns, opinions about sustainable growth vary widely among the policy makers and stakeholders. Two distinct points of view continue to persist: "Environment focus with a sense of urgency", and the "economic growth first, everything else secondary". The first one supports "let's get of rid carbon as soon as possible", and the latter one supports "climate is not the primary driver". Environmental proponents focus on long term issues and protecting the planet from degrading to new levels of point-of-no-return. Economic growth proponents, on the other hand, focus on the short term gains in power, security, and perceived quality of life.

The current short term economic considerations have limited our ability to invest in new low carbon energy supplies. In democracies, where most of the world lives today, politicians are more concerned about meeting short term needs for jobs and economic growth which helps them get elected and re-elected, than for the long term needs of society. Cleantech options need to be positioned as meeting short term job and economic needs, while at the same time providing a path for mitigating future harm from climate events.

Public is more aware now than ever before. Social networking and mobility solutions have changed the way the world population is participating in determining its future and influencing political process in an unprecedented way. Social networking platforms can enhance dramatically the way energy is used and efficiencies are achieved, as well as influence the political process that controls the use of energy and renewable deployments.

Sustainability is about long term. Economic growth can't continue indefinitely if the major underlying issues are not addressed. Further technological innovations, continuing emphasis on bringing science to society, and responsible political actions are needed.

2.3 Sustainability Megatrend

Although regulatory compliance to reduce and report carbon footprint started out as the principal sustainability concern for most corporations, a new trend has emerged that links sustainability as the driver for innovation to increase profitability while ensuring corporate social responsibility. The business sectors most impacted and embracing this trend include transportation, communications, agriculture, manufacturing, and retail along with their supply chains.

A Harvard Business Review article in 2010, Sustainability imperative suggested that sustainability has emerged as a new megatrend much like "Quality megatrend" in the 70s and 80s and the "IT megatrend" of the 80s and 90s, and outlined the following four stages of value creation based on the lessons learned from these previous megatrends.

1. Do old things in new ways: Focus on reducing cost, risks, and waste.
2. Do new things in new ways: Redesign products, processes, or business functions to optimize their performance.
3. Transform core business: Drive revenue growth by integrating innovative approaches into core strategies.
4. Differentiate value propositions through new business models.

Businesses in all sectors are recognizing sustainability as an opportunity for dramatically increasing efficiency while building relationships with suppliers, the government and with the society. And they are creating innovative and effective cleantech solutions by leveraging advances in mobility, social media, and information systems technologies. Companies are discovering that what is good for the planet can be good for their bottom line.

Many multinational corporations and innovative startups funded by venture capital are taking an active role in this "sustainability megatrend" and positioning themselves as first movers and market leaders.

Sustainability, from environment standpoint, is being addressed on three frontiers:

- Resource availability (energy and water supply) for consumption and economic growth while protecting the environment and ecosystem.
- Conservation and efficient use of these limited resources (energy and water demand).
- Building resilience to natural disasters and extreme weather/climate events.

In his book, "Kick the Fossil Fuel Habit" published in 2010, Tom Rand (MaRS) outlined 10 cleantech technologies that could save our world. In the following sections, we will look at some leading examples of emerging cleantech solutions today.

3. Quest for Clean Energy

3.1 Renewables

Global new investments in clean energy grew rapidly from $187 Billion in 2009 to $302 Billion in 2012 and then saw a decline to $269 Billion in 2012. China is leading the way with $65 Billion investment in 2012, with the US being #2 with $35B investment. With large investments and creativity unleashed, significant progress has been made on several fronts. Renewables constitute about 15% of the total energy mix in the world today, and could rise to 25% by 2018 .

Figure 4. Solar and Wind Power are leading the way for renewable energy with emerging price parities versus fossil fuel based energy

Although the renewable industry suffered somewhat from the failure of Solyndra (faulty business model) and Suntech (over-production), solar installations have increased significantly with the same technology (crystalline silicon, collectively abbreviated as c-Si) because new business models were developed by companies like SolarCity, which is showing tremendous growth with their no-money-down lease option and 20-year power purchase agreement.

Both Solar and Wind power prices have dropped steadily with technology innovations Determining price parity for renewables compared to fossil fuels is complex as it depends on several factors including cost of intrinsic new technology, new versus existing infrastructure, variable government subsidies, political uncertainties impacting fossil fuel prices, and the true cost of carbon injection into the environment.

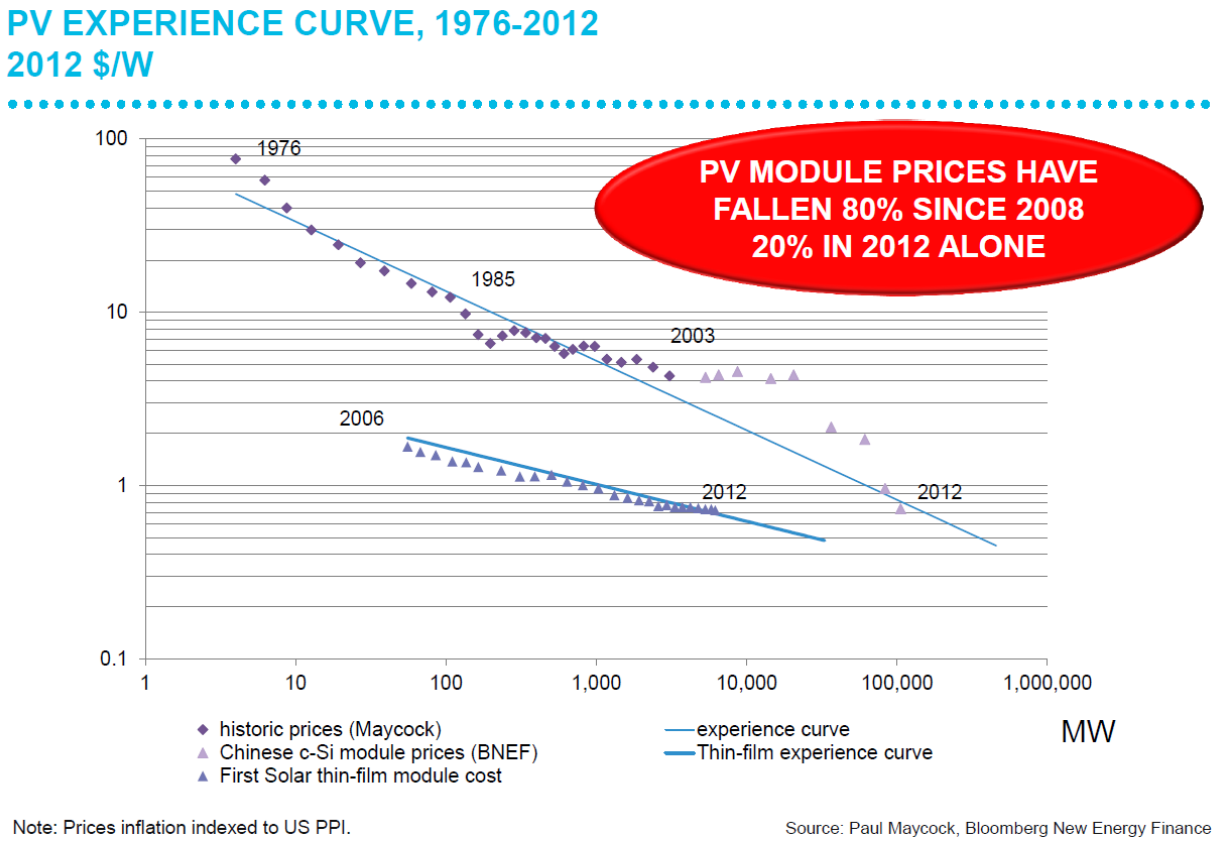

Figure 5. Solar PV module prices have dropped steadily over time
(Source: Michael Liebreich, Bloomberg New Energy Finance, Delhi, 17 April 2013)

Solar has emerged as a disruptive technology - while conventional energy prices remained pretty flat in inflation adjusted terms, the cost of solar is dropping fast and is likely to continue doing so as technology and manufacturing processes improve. Bloomberg New Energy Finance reported in April 2013 that (a) solar PV module prices have fallen 80% since 2008 and dropped 20% in 2012 alone (Figure 5), (b) wind turbine prices have fallen 29% since 2008 (Figure 6), and (c) EV battery prices have also fallen 40% since 2010.

Both solar and wind are beginning to get price parity and could reach a reasonable part of the energy mix in the near future. Wind has already reached parity with coal in India.

Green Power Labs, a Canada based company providing predictive analytics software tools for solar power planning and installation to utilities in many countries, emphasizes that in comparing prices one needs to consider if there is existing power infrastructure (already paid for) or not. In places where there is no existing grid infrastructure (as in some developing countries) or where electric prices are already high, solar has already reached parity with conventional energy. For example, in Hawaii, the cost of building infrastructure for transmission and generation from coal and nuclear would be high, and solar is a viable alternative.

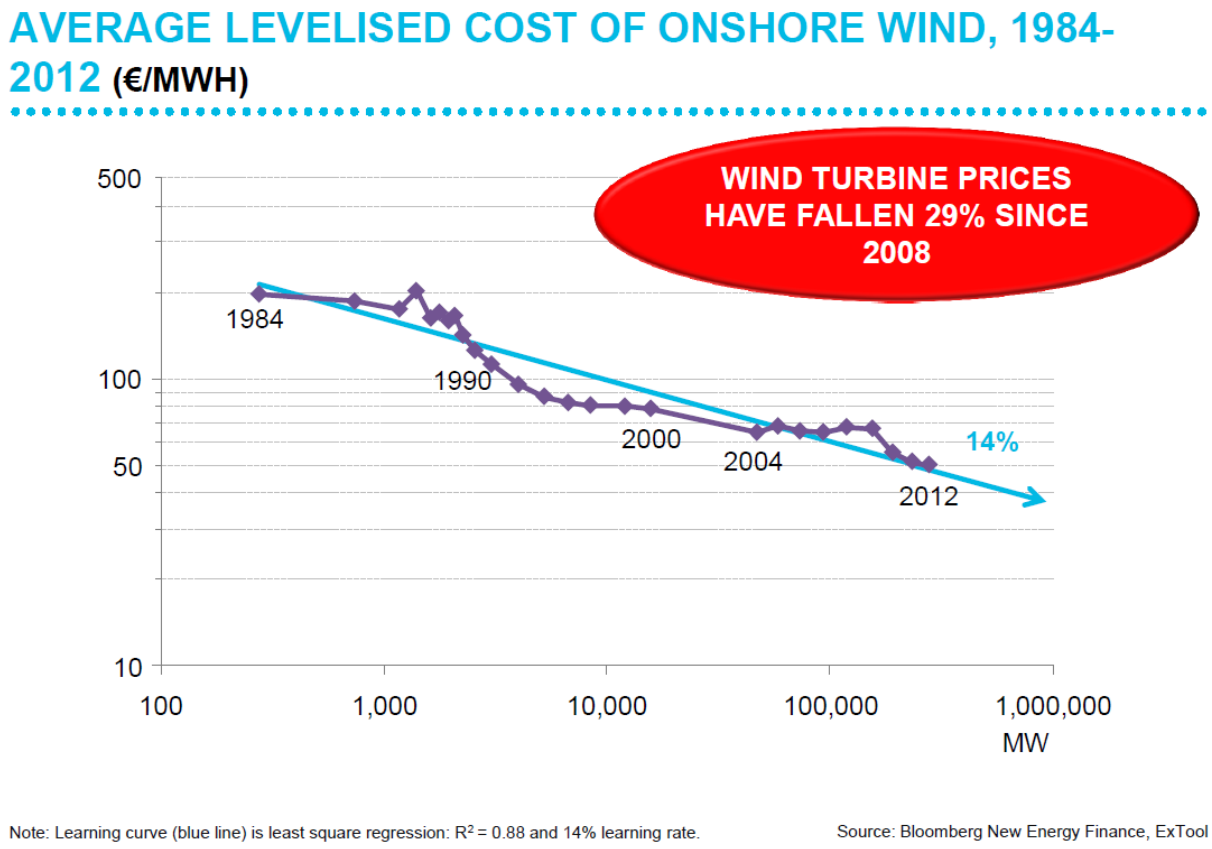

Figure 6. Wind turbine prices have dropped steadily over time
(Source: Michael Liebreich, Bloomberg New Energy Finance, Delhi, 17 April 2013)

Among other sources of renewables, nuclear and biomass have received substantial attention. Waste is a concern in both cases, and technology to handle it safely is evolving. Next generation of nuclear breeder reactors with burning existing waste, have enormous potential. This is particularly significant since France already derives over 75% of its electricity from nuclear energy, and other countries, notably India, Argentina, and Middle Eastern countries, have major nuclear energy plans.

EnagraTech, an innovative startup, has developed a thermochemical process that replicates Earth's process of using temperature, pressure and water to convert biomass into a crude oil like product, dubbed as "GreenCrude". This also solves the waste disposal issue and environmental degradation (e.g., in palm oil production) while providing an energy source in areas with ample supply of biomass.

Consumer Scale Deployments

SunFunder is leveraging crowdsourcing to enable funding for solar energy micro-businesses addressing a market of 1.5 billion people around the world who do not have access to electricity but have plenty of sunshine to generate electricity – thus creating an off-grid revolution. Access

to local data and mobility solutions is at the core of planning and implementing these "local" solar energy solutions. A recent project involves partnering with local power companies in Uganda (Figure 7) to facilitate entrepreneurs setting up solar powered charging stations for cell phones. This is much more cost effective and convenient for the consumers than the previous car battery based charging stations at distant central locations.

Figure 7. An entrepreneur in Uganda provides solar powered charging station for mobile phones (Source: SunFunder, 2013).

Mosaic, another crowd-funding startup, is on a mission to open up clean energy investing to the public and fundamentally change the way energy is financed. As of April 2013, the company had raised $1.1 million from more than 1,000 investors to fund 12 rooftop solar power plants. Recently, Mosaic received regulatory approval for its next wave of crowd-funding efforts in California.

Corporate Scale deployments

Terrapass , an emission reduction and renewable energy consulting service provider to corporations, is finding that more and more corporations are installing on-site or local sources of renewable energy. Solar power, fuel cells, and wind power are being used depending upon the local environment. Many start with buying carbon off-sets, but gradually migrate to their own few MW renewable plants. In IT space, larger players such as Google, Apple, Microsoft, went from small initiatives to building own power plants. Apple, working with NV Energy, a utility company in Nevada, is planning to build an 18-20 MW solar panel farm for its new data center in Reno, Nevada. Google has recently invested $200 million in a utility-scale wind farm developed by a San Diego renewable energy developer.

Utility Scale Deployments

Some operations issues need further attention for utility scale installations. Both wind and solar are intermittent, and neither can provide a complete stand-alone solution unless there is sufficient storage, or direct connectivity to the grid for load balancing and sharing with other sources of energy. Scalability can be challenging also, as for example one would need 3000

wind farms (1 MW each) to replace one coal-fired power plant, or to move one nuclear power plant off-line.

Smart Energy Instruments, a Canadian startup with presence in Japan and supported by Silicon Valley VCs, is building chipsets to enable solar and wind connectivity to grid, enable grid observability (grid stethoscope), allow sustainable renewable production, and manage a mix of renewable and conventional energy. These chipsets will enable sensors to collect data at a very fast rate. The technology breakthrough gives unparalleled visibility into the grid and could be a game changer.

Without energy storage in the smart grid, renewables can only go so far, therefore storage remains the holy grail of renewable energy. Substantial investments are being made in innovative technologies and the progress is promising. Companies such as Hydrostor, Deeya Energy, and others are developing storage solutions that could make a big difference in renewables adoption on a large scale.

Innovation is needed in tidal, geothermal, and nuclear fusion to be viable alternatives. Nuclear fusion will take some time before it reaches the market - even after the technology is proven in the lab and solutions are found for safe waste disposal, it may take more than 15 years before it can be scaled up and gone through the regulatory hoops.

At the utility scale, renewables project finance is challenging and is hampered by two systematic economic effects – market externalities, and embedded cost of capital. In addition, when new technology appears with a first prototype, there is risk involved in building an operational system and then scaling it. Utilities and normal project finance investors want the concept and technology to be fully tested out first before they would commit. Since no one wants to take the risk, financing for building the first fully tested operational system is very difficult today. A financial vehicle for that first project finance is desperately needed and investors in the industry need to come together to find a solution.

3.2 Unconventional Energy and Energy Mix

Recent emergence of abundant and low-cost shale natural gas and shale oil has changed the global energy power balance dramatically. In the US, the availability of this new affordable source of energy is being seen as the road to energy independence. Since shale natural gas has a lower carbon footprint than coal, it is deemed to be a step in the right direction from environment standpoint. But, it will still be adding carbon to the atmosphere, and has significant air and water pollution issues that are currently being debated.

Although oil and gas are relatively cheap today in North America, one has to really look at the true cost of fossil fuel by including what it does to the environment. Moreover, uncertainties exist about how political unrest in certain parts of the world could impact natural gas and petroleum prices in the future. Even in the US, pressures to export natural gas could result in domestic price increases.

Leaders in Oil and Gas sector, the dominant supplier of energy today, contend that while the renewables are growing, the demand is so huge and so much is invested in the current

infrastructure, that the fossil based fuel based energy could remain a large percentage of the energy mix for quite some time.

Rapid rise in natural gas from shale fracking is keeping the gasoline prices low in the US (because of the availability of petroleum along with natural gas). If price of petroleum stays low, the challenge to migrate away from fossil fuel becomes even more daunting. If the US starts exporting natural gas, prices could increase to parity levels in other countries.

In an article, "Yesterday's fuel", published in August 3, 2013 issue of The Economist, the author argues that we may have already reached the peak of oil demand, and shale gas could dominate the energy mix in the near future.

The growth of shale gas enabling the availability of cheap natural gas cannot be underestimated or downplayed. Energy is a commodity and thus price tends to drive decision making. Natural gas will have a huge impact on the future of energy over the next few decades. Although developed in the US, the technology is quickly spreading to China and Europe.

Carbon pricing (subsidies, tax, and emissions trading) has a critical role to play in how the energy mix will evolve over time. Nuclear energy is also making a comeback and could be a significant part of the energy mix. Improvements are needed in all the areas that could make a positive impact to ensure sustainability – these include technology innovation, business practices, and government regulations. Numerous opportunities exist for public-private partnerships to make this happen.

4. Energy-Water Nexus

4.1 Freshwater Availability

The Club of Rome was not taken too seriously in 1970, when they claimed that the world had finite constraints that would limit growth - we are finding out today, albeit painfully, that this is true. Due to environmental impacts and rapid use of natural resources, freshwater shortage is already evident in many parts of the world affecting local food supply and public health.

In 2008, global demand for water exceeded supply, so now we already have a deficit! Projected year 2025 water demand to support population and industrial growth may exceed supply by 56%. We are using up our reserves of freshwater - rivers, aquifers and lakes are drying up. Moreover, industrial pollution is making water unsafe. And hydropower production is declining due to lower water level in reservoirs (Lake Meade - Hoover dam, Lake Lanier - Atlanta).

Indeed, freshwater has now become the most critical resource in the world to ensure survival and healthy growth.

4.2 Low Carbon Energy vs. Water Conservation Trade-offs

Energy and water are deeply intertwined as water is needed to produce energy and energy is

needed to produce water. Significant tradeoffs exist today in low carbon energy generation and water conservation. Low carbon often means high water consumption.

Biofuel production has been a high US government priority, but biofuels are heavy consumers of water. In producing corn based Ethanol, it takes on average about 3000 gallons of water to make a gallon of fuel, whereas it takes on average 9 gallons of water to make a gallon of gasoline with oil resource. Diversion of corn into production of ethanol led to severe impact on corn prices in Mexico , and significantly affecting food supply.

Concentrated solar power generation with steam turbines needs much more water compared to the same amount of power generation from a coal burning power plant. Furthermore, a coal power plant with a scrubber will take 3-4 times the water than the one without the scrubber, and also increases water contamination.

With fracking of shale gas, there are three major issues relating to water.

- Requires drilling down to more than 10000 feet, and that means going through existing freshwater aquifer – so there is potential for contamination. The recycling of fracking water can increase the amount of contaminants that shale gas drilling is exposing the groundwater to even further.
- Various chemicals are added in the water to enable fracking and leakage of these can have environmental impacts.
- About 3-5 million gallons of water is needed per large well, and the water that comes out is much more salty than sea-water and is tough to treat.

The larger corporations leading fracking operations are much more risk averse than the smaller ones. Wellbore technology improvements have greatly reduced probability of contamination. Also, the chemicals being used are more organic, and less toxic. Pre-treating of water before injecting in the wells has made a big difference. Overall water reuse is significantly better than it was only 3-5 years ago.

Air and water pollution from fracking is being monitored, albeit it could be better. Environmentalists have raised many issues. Supporters of shale gas claim that economic growth has been held back to understand and minimize environmental impacts – especially water quality. This issue is subject to debate; an EPA investigation is ongoing and a new report is expected in 2014.

Pressure on water sources in North America with the arrival of unconventional gas is becoming bigger and bigger. Water sources are not endless and tremendous innovation is needed in both water availability and efficiency of water use. Major need exists in new oil and gas exploration and cleanup technologies that require a lot less water.

4.3 Water for Thermal Power Plants

“In the United States, 90 percent of electricity comes from thermoelectric power plants—coal, nuclear, natural gas, and oil—that require cooling. The remaining ten percent is produced by hydroelectric and other renewable energy facilities.”

Water used for cooling is the primary concern in Thermal power plants. In the old water pass-through systems water loss was minimal through some leakage. In cooling towers, which is the current trend, evaporative loss became the primary loss mechanism. Competition for scarce water could constrain thermoelectric power production.

It is important to distinguish between water withdrawals versus water consumed in energy generation to better understand the energy-water relationship. The fresh water withdrawals in the US are about the same for agriculture as that for thermoelectric energy production, but most of the water used for thermal energy is returned while there is significant loss of water in agriculture case (discussed further below).

Seventy percent of the water used for thermoelectric cooling is fresh water from rivers and lakes, and the quality of water returned is questionable. There are significant concerns about protecting marine life where water is released into streams by thermal power plants.

One alternative is dry cooling towers, which don't need water but they require substantial amount of energy and can have 3-9 times the carbon footprint of water cooling towers.

4.4 Water for Agriculture

Irrigation for agriculture and thermoelectric power plants require the largest withdrawals of water with roughly equal amounts, hence the two sectors compete for water. Water for irrigation makes up 40 percent of total withdrawals, but it comprises more than 80 percent of the 100 billion gallons of water consumed daily in the U.S.; these losses occur due to evapotranspiration. About 40 percent of water withdrawn for irrigation is returned for re-use, whereas almost 98 percent of withdrawals for thermoelectric cooling are returned (albeit, the quality of returned water can be questionable as discussed above).

As water resources become constrained, concerns about water availability for agriculture versus that for energy loom on the horizon. A major threatening issue is water rights trading, as farmers in the US are selling their right for water to other industries as they can make a lot more money by selling water rights than selling crops. Issues have begun to appear about farmers choosing to sell their water rights, for example, to oil and gas developers for fracking.

But there is a lot that can be done to make more efficient use of water for agriculture and avoid high water use scenarios such as growing water-hungry crop (e.g., rice paddies) in high desert.

Smart irrigation (Figure 8) is particularly important since agriculture is a big user of water today, and a significant fraction of water is being wasted. New low-flow technologies from companies like Toro or Rainbird can reduce water demand for agriculture by 50-70%. But in the US, water is heavily subsidized for farmers, so the motivation to conserve seems to be lacking. Ironically, Farm subsidies for efficient irrigation systems have led to *more* water use as farmers are using the savings to irrigate more land rather than to conserve diminishing sources of ground water.

HydroPoint, a Chrysalix portfolio company, uses weather forecasting network data to provide intelligent irrigation management systems – that is, not irrigate when raining, and irrigating only when needed, for example in the growth process.

Figure 8. A pivot sprinkler system waters crops in the Kells Farm Partnership in Kansas. (Source: New York Times, June 7, 2013)

Water use and efficiency are obviously important, but a bigger concern is in aquifer depletion that is critical for agriculture in many parts of the world. In this case it is water that had left the natural cycle of evaporation-condensation, and effectively been sequestered. Regional water scarcity has become a serious and growing problem, as rapidly growing populations in many areas rely on regional water supplies which are being depleted, degraded, and divided among more and more users[1].

Alarmingly, aquifers in some of the world's major agricultural regions, including China, India and the United States – all of them crucial to the food security of 100s of millions of people – are being exploited unsustainably. Recent results from the GRACE satellites show that ground water is being heavily depleted in all of the major groundwater dependent irrigation areas including India, North China, California's Central Valley, Southern High Plains in the US, and the Tigris-Euphrates basins.

Water shortage has impacted agriculture in China where acreage of farming is declining. China, anticipating a food shortage in the next 20-30 years, is investing in ownership of farm land in Africa to feed its population.

Climate change may be exacerbating the groundwater shortage for agriculture. Prolonged droughts and depleted glacier-fed rivers are direct consequences of climate change. Reduced rainfall decreases the rate of aquifer re-charge. The entire ecosystem is interconnected and requires a systemic approach to assess the issues surrounding energy-water-climate nexus.

[1] Gleick, P.H. and Palaniappan, M. (2010) Peak water limits to freshwater withdrawal and use. Proc. Natl. Acad. Sci., USA, 107: 11155-11162

5. Business Infrastructure and Operations

Big corporations worldwide are taking action to reduce their carbon footprint. As regulatory frameworks on businesses are emerging regarding control of GHG emissions, businesses are taking proactive initiatives. Large consulting firms such as McKinsey, Deloitte, and Ernst and Young are helping them develop strategies to ensure their growth in the carbon constrained economy and increase profitability through improved energy and carbon management.

In this section we take a look at sustainability challenges and selected best practices in transportation, telecommunication, manufacturing, and retail sectors.

5.1 Transportation

Transportation is the second largest source of America's emissions, just behind power plants. The biggest contribution of the automobile industry to atmospheric greenhouse gases is emissions from the tailpipes. Leading automakers and transportation industry giants are taking sustainability seriously.

The first step is to make vehicles more fuel-efficient, as US has set higher fuel efficiency standards. Automakers are putting much more focus on better gas mileage and it is indicative of a change in mindset. The next step is to offer hybrids with fossil and non-fossil based fuel, then electric, and later hydrogen powered vehicles. The cost of non-fossil fuel based technology to deliver eventually no CO2 is very high today, much higher than what the customers are willing to pay.

Ford 2012/13 Sustainability Report outlines its strategy and actions being taken - "we structure our core business model around using resources responsibly to create long-term value as a corporate citizen and global competitor". The company is developing three types of electric vehicles– hybrid, plug-in hybrid (15-30 mile), and pure battery based.

Chevrolet has introduced their electric car, Volt 2013, with a 30 mile range and an onboard generator to charge the vehicle if needed.

In the next 5-10 years, automakers expect a noticeable move toward hybrids, the most cost effective of the three EV options, and which may see "value parity" first with fossil fuel based vehicles. Plugin hybrid is far more expensive than hybrid, and is far from seeing parity in the foreseeable future. Pure Battery based EVs appear to be nowhere close to parity with gas, although battery prices will come down as technology improves. There's also the question of the electrical infrastructure upgrades required to support a high volume roll-out of EVs.

Package delivery companies like FedEx and UPS have come a long way in a relatively short time regarding sustainability by greening their ground fleets, optimizing their choices of transport modes, and streamlining energy use.

UPS was an early adopter of cleaner vehicles, and today operates more than 2,500 low-emission vehicles that run on alternative fuels and technologies.

FedEx also has one of the largest hybrid-electric fleets in the industry with over 2,000 alternative energy vehicles in service worldwide. While these trucks initially cost more than their traditional counterparts, the upgrade is expected to save much more, while substantially reducing emissions, over the lifetime of each vehicle.

"We at FedEx are operating several [electric vehicles] today. They cost about 75 to 80 percent less to operate per mile than their internal combustion counterparts," said Fred Smith, CEO of FedEx in a presentation to ARPA-E summit in 2012.

By March 2013, FedEx had already exceeded its original goal of improving efficiency (set in 2008) seven years ahead of schedule (with an overall savings of 22 percent up to that point) and was also upping its goal to a 30 percent fleet-wide efficiency gain by 2020.

Verizon's Green Fleet in New York – "25 MAGIC buses transporting company technicians to and from job sites replacing 250 technician trucks" – is an example of a successful implementation of green initiatives by taking the concept to the next level.

Vehicle to Vehicle Communication

The Role of IT through Vehicle to vehicle communication (V2V) is a huge factor in improving efficiency. Today, cloud information such as routing from point A to point B, is available and contributes to convenience and saving time which is the big constraint for most people. V2V communication is where innovation is happening now to enable safety and it has the potential to drive cost out of the vehicle (may not need as much costly safety structure!). Ford is rapidly expanding its commitment to intelligent vehicles that can wirelessly talk to each other and enable safety (Figure 9).

Figure 9. Vehicle to Vehicle communication can change safety and reduce carbon footprint (Source: Consumer Reports 2013).

Elements of location based services, e.g., the nearest gas station or charging station, place to eat, available parking etc. are available today and could be enhanced. This will help efficiency, fuel usage, and help in traffic congestion. If the car gets into an accident, and auto notification is sent to authorities to send help that is a positive use of location based services. Privacy concerns have popped up however, and that is a current issue for FCC.

Hughes Telematics acquisition last year put Verizon into a brand new business – putting telematics solutions in connected cars that enhance safety, security, and convenience – empowered by 4G wireless backbone and managed through the cloud. By learning about traffic patterns, telematics solutions reduce idling time, hence less fuel consumption. Verizon expects the implementation in its own fleet to increase productivity and cost efficiencies as well as help further reduce emissions as part of the corporate sustainability goal of decreasing its carbon footprint.

Consumer Use

Shared public transportation (Buses, shuttles, trains, rental cars), improvement in infrastructure and information services (e.g., wait time for the next bus), and improving efficient use of fuels- offering less CO2 emission per person – have significant opportunity and potential to reduce carbon footprint. US individual car ownership and driving patterns are changing. Americans are buying fewer cars and driving less. Hourly and short term rental cars such as ZipCar are getting traction as a result. Although in many places, the problem is that ample public transportation is there but people are not using it. Mixed use of public and private transportation (e.g., driving to metro station and then taking the train to the downtown business district) is happening more and more in big cities.

5.2 Telecommunications

Major telecom carriers are committed to reduce their carbon footprint by planning and implementing sustainability efforts, improving their own operations, deploying energy efficient network components and end user products, and leveraging renewable sources of energy to provide backup power for cell towers in remote locations.

Energy consumption in networks as well as by end user devices is a big issue for communications services and equipment providers. With proliferation of electronic devices ranging from personal and mobile devices (cell phones, tablets, audio players, laptops), to in-home entertainment appliances (set top boxes, PCs, televisions) – a big challenge that information and communication industries face is how to enable technologies in the wireless and wireline world in the most energy efficient way.

Operations

Carriers are strongly focused on energy conservation as an enabler for new business models. This includes smart building technologies, HVAC efficiency, remote controls, lighting and water sensors, and facilitating remote tech with access to data via cloud.

Verizon has reduced its carbon footprint by 37% since 2009, and is targeting a 50% reduction by 2020. According to Verizon's chief sustainability officer and vice president of supply chain, James Gowen, sustainability matters, "Sustainability is part of Verizon's shared success philosophy – by doing better environmentally, we have realized improved business operations, cost cutting, and most importantly, a better outcome for the communities we service, and our children's futures.

Figure 10. Verizon's MAGIC Bus. Photo - courtesy of Verizon.

Verizon's Green Fleet, which includes a first of its kind "25 MAGIC bus" system (Figure 10) in New York and Washington D.C.", transports company technicians to and from job sites, replacing 250 technician trucks" – is a key example of implementing a shared success philosophy via green initiatives, by taking the concept to the next level. A 90% of Verizon's eligible stores are classified as ENERGY STAR® stores. Verizon was one of the winners of ENERGY STAR partner of the year award in 2013.

AT&T organizes its sustainability initiatives into three focus areas, which reflect the issues the company feels embody its commitment - People and Community, Environmental, and Innovative Technology. In the AT&T 2012 Sustainability Report, the company reports that 14,300 projects saved the company more than $151 million in annualized energy savings since 2010 and nearly 1.3 billion kilowatt hours (kWh), equivalent to the electricity use of 136,340 homes in one year.

In an effort to empower AT&T customers with sustainable choices, increase efficiency and minimize impact on the environment, AT&T is teaming up with The Nature Conservancy to encourage its customers to skip the bag when purchasing items from its retail stores in Colorado, Utah, Alaska, and other states.

In a 2011 Newsweek survey of 500 largest companies, Sprint ranked #3 among America's greenest companies (behind IBM and HP, and the highest of any telecommunications

company). After completing a materiality assessment in 2008, Sprint determined which operational impacts were the most critical and created a set of 10-year goals that would reduce its environmental footprint. Since then, the company has made excellent progress against these goals.

Sprint Biz 360 solutions have helped small companies better deploy their mobile workforce while reducing their carbon footprint. And by reducing the amount of electricity and fuel they used, the company also helped their bottom line.

Renewables

"Fuel cells are increasingly being used for backup power in the telecommunications sector. Verizon has invested $100 million in a solar and fuel-cell energy project that will help power 19 of the company's facilities in seven states across the country: Arizona, Maryland, Massachusetts, New Jersey, New York and North Carolina. The project will be completed in 2014 and will enable Verizon to generate more than 90 million kilowatt hours of its own green energy annually. With this initiative, Verizon will eliminate more than 15,000 metric tons of CO2 each year -- equivalent to the annual CO2 emissions from more than 1.6 million gallons of gasoline consumed.

In 2009, DOE awarded $18.5M in Recovery Act funding to three projects for fuel cell deployments in backup power – ReliOn, Inc., Sprint Nextel, and Plug Power, Inc. Hydrogen fuel cells support Sprint's ambitious environmental priorities, which include reducing greenhouse gas (GHG) emissions by 15 percent and securing 10 percent of Sprint's energy needs from renewable sources by 2017.

ReliOn, Inc. (with fuel cell deployments at AT&T and Pacific Gas & Electric sites) and Sprint are demonstrating the technical and economic viability of deploying fuel cells with 72 hours of on-site fuel storage to provide backup power for critical cellular tower sites and utility networks.

AT&T is also making efforts to increase the amount of energy derived from alternative sources, including fuel cells, solar power, and wind. With a second wave of fuel cell installations in California and Connecticut, AT&T facilities will produce 17.1 MW of cleaner power from Bloom Energy. The company is looking for business cases that offer both environmental and financial benefits for their use.

Recycling

With technology changing fast and newer, faster, more feature rich consumer devices (smart phones, tablet PCs etc.) being made available every year, a major challenge technology companies and consumers face is recycling of obsolete (albeit functioning) electronic devices. The US EPA estimates that about 135 million cell phones are discarded every year and reusing or recycling these phones could save enough energy to power more than 24,000 homes for a year.

Sprint recycles its customers' old phones free of charge–and aims to collect 90 percent by 2017. It has also developed an eco-logo to help consumers identify earth-friendly devices.

Verizon recycled or repurpose 28% of all devices in 2012 by using incentives such as store credit for recycling, or plant a tree in honor of trade; the company plans to increase that number to 33% by 2015.

Through the AT&T Trade-In Program, consumers are invited to bring unwanted wireless phones, smartphones, accessories and batteries* (regardless of the manufacturer or carrier) to AT&T company-owned retail stores for recycling.

5.3 Manufacturing and Retail

Wal-Mart, the largest retailer with global supply chain, began implementing an aggressive sustainability strategy in 2004. One of Walmart's three overarching goals was to be supplied by 100% renewable energy. Although not the first one to do this, the company made a strong effort to see sustainability in a different way. Sustainability became a way to expand systems level thinking. Wal-Mart's partnership with the international Carbon Disclosure Project allowed opportunity to listen to different supplier viewpoints, gain transparency into efficiency of supply chain, and form better operations frameworks more directly aligned with business goals. The company has now successfully embedded sustainability into core business strategy, just like low prices, rather than simply stop at regulatory requirements.

In 2012, Verizon[2] went to its top 250 suppliers – 80% of the total, and asked how they measure GHG/ CO2, water use, waste program, etc. Low performers were asked why they did not address GHG issues and how that performance can be improved. By 2015, the company plans to devote 40% of effort on those who support GHG targets; this has global impact.

Saint-Gobain, with a huge manufacturing and distribution network is focusing on energy efficiency in construction materials for roofing, windows, siding, and gypsum insulation. The company is facilitating technology transfer from startups into mainstream products. A notable example is leveraging of electrochrome technology to create glass with "double/triple insulated glazing, which, under a low voltage current can be switched from clear to darkly tinted (and reversibly) while remaining transparent". This can be used to build the next generation of energy efficient windows that tint automatically as the outside temperature changes. Since most energy loss occurs through the windows, it is a big step toward enabling building efficiency.

Availability of abundant natural gas in geographies like North America is likely to slow down the transition to renewable fuels and chemicals production[3]. Natural gas is the basis for petrochemical industry today in North America. In order for renewable to make significant headway in the market they must provide the same cost and performance or have a supply chain that is willing to pay a premium. For example, High Density Polyethylene (HDPE), the plastic we associate with milk jugs and liquid laundry detergent bottles, is mostly derived from

[2] James Gowen (Verizon), Keynote Presentation at Cleantech Forum, San Francisco, March 20, 2013
[3] Tony Kingsbury (Cardno ChemRisk), Sustainable Sourcing: The Quest for Innovative Chemicals & Materials", Panel discussion, Cleantech Forum, San Francisco, March 20, 2013

natural gas. Converting corn or sugar cane to ethanol and then to polyethylene can and is being done (e.g., Braskem's green polyethylene plant in Brazil). However, this "green" polyethylene can't currently compete on price in North America as long as natural gas is cheap. This doesn't mean that companies aren't using this bio-based polyethylene in NA; it just means they must pay a premium. As more companies signal a desire to move to bio-based materials the large investments needed to bring these materials to the market will increasingly emerge. As gas prices rise and the cost of producing bio-based materials drops, one would expect to see more companies making the switch.

6. Information and Communications Technologies

Connectivity and access to information is critical for consumers, businesses, and governments alike. Information and Communications Technologies, therefore, have a major role in (a) enabling efficient day-to-day business operations and consumer activities, (b) proactive resources planning, and (c) emergency preparedness and disaster response.

In fact, the focus on sustainability is reviving old and established communications services like video conferencing, fleet telematics, and telecommuting. It is also putting communications companies in position to compete for business in the rapidly growing markets for cloud computing, hosting, and vertical solutions for smart buildings, smart grids, remote monitoring, and electric vehicle charging. With this large opportunity, leading Telco services providers are putting sustainability at the center of their product strategies.

Exponential data growth is taking place today - IDC called it the digital universe (Figure 11). A part of this growth is due to more and more sensors being deployed in homes, commercial buildings, networks, and automobiles -- generating massive amounts of monitoring data to enable control, efficiency, and sustainability.

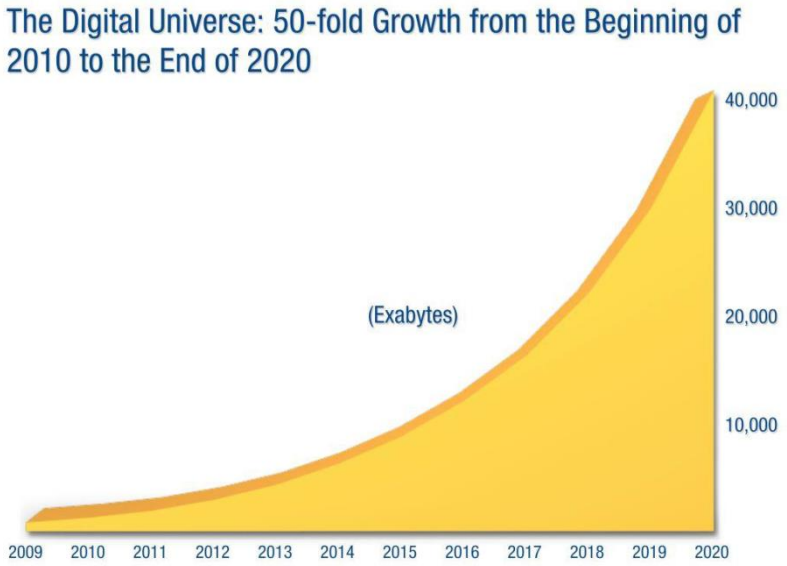

Figure 11. The Digital Universe: exponential growth of data (Source: IDC 2013)

A recent McKinsey study noted that "analyzing large data sets—so-called big data—will become a key basis of competition over the next 10 years". Big data is about offering intelligence with unprecedented information to unlock better insights into operations and customer applications (e.g., social networking).

Building state-of-the-art sensors and turning that data into meaningful information is where a huge opportunity exists for innovation to ensure sustainability.

6.1 Smart Grid

Big data is a tool for enabling better business models for the utilities. The data collected on end user behavioral patterns using smart meters and smart thermostats are very helpful to electric grid operators in determining load, managing over-production or under-production, understanding Microgrid operations and enabling efficiencies. Thus, intelligence for grid control needs to be at the edge – like computing control (see data center discussion below). As a result, different energy pricing models are emerging for utilities depending on the usage data and efficiency measures taken by the consumers. Such demand response has been successfully tested and deployed by NV Energy in Nevada with positive results.

Major savings and efficiencies can also be realized in the backbone of the smart grid network leveraging big data and smart IT solutions, since large utilities often do not have the visibility in their network. Major innovation opportunities exist here as well.

Claremont Creek Ventures portfolio companies, Ecofactor and Blue Pillar, are providing information systems solutions for monitoring and control of energy consumption at end points. Ecofactor is focused on residential heating and air conditioning use. Blue Pillar provides centralized oversight of campuses such as hospitals, universities, and industrial parks by using intelligent control systems monitoring multiple types of assets regionally but collectively.

Green Power Labs provides predictive analytics tools software to utilities, with focus on integration of local solar generation into the grid. This is enabling utilities to get better control in managing the grid. While smart grid is intended to support and manage local generation of electricity connected to the grid, utilities are still uncomfortable with handling individual ownership of local generation (e.g. residential rooftop solar). Once local generation reaches the tipping point, perhaps 20% of total from rooftop solar, utilities would get serious about managing this integration. Large investments are being made in the grid for future proofing with such scenarios. The challenge for solutions providers like Green Power Labs is to understand what data are needed, and how to present it to different utilities as they often have different systems.

One of Chrysalix's portfolio companies, EnBala, plays a significant role in this by enabling "a smart grid platform that changes the way system regulation and other ancillary services are provided by using load-side assets, rather than generation".

With proliferation of data, most utilities will have huge IT operations and the role of the CIO in utilities over the next 10 years will become much more important than it is today.

6.2 Efficiency and Conservation through IT

IT enabled sustainability (data access, collection, monitoring, and sharing) are becoming drivers for efficiency and conservation in practically all the major industries. Thanks to social networking platforms and major proliferation of mobility solutions, many startups are coming up with innovative sustainability solutions. Here are some examples.

Airbnb is an example of increasing efficiency by sharing unused commodity through data – a giant inventory of places to stay around the world as an alternative to hotels.

Cleanweb is a grassroots effort launched in 2012, where cleantech meets the cloud and where sustainability meets social media. Its mission is to facilitate entrepreneurs and intrapreneurs within companies of all sizes around the world to develop creative solutions for resource issues. These incubators, with an eye toward scalability, will comprise of individuals with expertise in Data science, OpenData, and Visualizations. Successful weekend hackathons and developer day events have been held in several megacities including San Francisco, NYC, Boston, Chicago, and Milan. For example, in Chicago, Cleanweb is serving as a bridge between city hall and local incubation hubs like "Chicago 1871", with support from Mayor Rahm Emanuel. In the disaster response arena, examples of Cleanweb hackathons apps include forecasting of which buildings are likely to get flooded in case of storm surge, and how to support Red Cross in coordinating critical resources (water, food) for stranded workers. The C40 Cities Climate Leadership Group (C40), under the leadership of NYC Mayor Bloomberg, is mapping big issues surrounding sustainability plans for megacities that could serve as drivers for Cleanweb incubators around the world.

Indiegogo promotes crowdsourcing of all sorts of sustainability efforts under "fund what matters to you" banner all over the globe. Crowdsourcing is helping in developing sustainability ideas especially in countries where the government is proactive in supporting green initiative and where World Bank is taking an active role in funding sustainability programs.

Mint.com, a provider of online personal finance management software, would not have been possible without the availability of banking and transactional data.

Nest is providing smart thermostats that learn as they leverage consumer energy usage data along with environmental information. It learns consumer's behavioral patterns from sensors, such as when you are away from home, and creates a temperature-setting schedule from them. The end result is much more efficient energy usage for heating and cooling.

Waze , a social GPS, monitors upstream traffic by looking at smartphones and GPS devices in the automobiles on the road, synthesizes data in real time, and provides traffic alerts and recommendations. Avoiding congestion from better information does a lot for miles per gallon, and thus reduces fuel consumption.

Yerdle, an innovative startup leveraging social media for cleantech, is making use of shared information to achieve efficiency and reduce waste, thereby creating a strong sustainability platform. "Getting something that is sitting in your neighbor's garage and not being used is much more efficient than producing and shipping it from another continent". By promoting this sharing

among friends, the company's goal is to reduce pure production by 25% for new items that are being manufactured right now globally.

As evident from these examples, the encouraging trend is that as IT capabilities and services evolve, more innovators and entrepreneurs are able to access data that would otherwise sit idly in massive government and private sector databases. Availability of this structured data will allow entrepreneurs to compete for better ways of making data more useful and thus create innovative solutions.

6.3 Cloud Computing and Data Centers

The expanding role of IT in organizations, big data and proliferation of cloud computing are requiring unprecedented growth in data-centers. NIST defines Cloud computing as encompassing use of (a) "public cloud" (e.g., Internet-delivered service), (b) community cloud (e.g., enabling shared community concerns such as mission, security, other), (c) "private cloud" (e.g., in a private organization's infrastructure), and (d) "hybrid cloud" (composition of two or more of private, community, or public clouds).

Cisco forecasted that 2014 will be the first year when the majority of workloads shift to the cloud, and that global data center traffic is expected to grow fourfold from 2012 to 2016 reaching a total of 6.6 zettabytes annually.

U.S. Department of Energy estimated in 2010 that data centers consumption is 1.5% of all energy consumed in the US. This number is expected to grow at 12% per year, doubling in about 6 years. Indeed data-center efficiency has come under scrutiny - a NY Times article, published on 22 September 2012, stirred up major discussion by alerting that many data centers are not very efficient, running at only 7-15% utilization and wasting a lot of energy.

Figure 12. Data centers will become crucial to energy debate as "big data" increasingly drives business operations.

The biggest design driver for data centers is availability[4]. Cloud has a lot of potential, for example, by providing hot swap with a short notice, without having to have a hot standby – in that case what is good for the business is also good for the planet. For companies like Salesforce.com which provides cloud computing based services, and EMC which provides cloud computing platform, this offers a highly sustainable model.

Data center efficiency varies substantially and depends on a number of factors. The Green Grid organization is analyzing resource efficiency for all IT infrastructure including data centers, and over the entire lifecycle including disposable products. The Green Grid members strongly believe that investing in energy efficient IT contributes to GDP across all industry sectors. The sustainability goal is to track increased productivity and net impact on greater economy per unit of energy consumed.

Data center's carbon footprint comes from energy used to power IT equipment (servers, storage, and networks), cooling, and recycling, as well as the power distribution itself within a data center. This is not an issue for a data center if it uses renewable source of energy. PUE typically measures only power and cooling infrastructure efficiency, not the efficiency of data center as a complete system. The Green Grid recommends that metrics like PUE, CUE and WUE, which measure power, carbon and water usage, provide the tools to improve overall data center efficiency. But even these metrics don't get to "overall data center efficiency" in that they don't address the efficiency of the use of the IT assets. They do, however, provide a more holistic picture of the impact of the data center on the environmental systems.

Majority of the data center design driver is Capex – trying to avoid having to build another data center; the flip side is opportunity cost of expanding cloud. Next is Opex. Sustainability comes last although it has been on the rise.

Three kinds of barriers exist today for adopting green technologies in data centers - technical, cultural, and institutional[5]. An example of a major technical barrier is that the whole IT operation needs to be systems aware and operate at a system level not component level which is the case today in many data centers. Servers can go from maximum load to zero load, and the system has to recognize it so they don't have to blow maximum cool air when servers are running at zero load.

Next, new and helpful technologies exist but are not being used today, so it is a cultural hurdle. The current business priority is to ensure availability, not efficiency. Leading companies are more concerned about business delivery, customer requirements, production, and smart business management – being green is often a secondary thought. There is a need to build the business case but data are sorely lacking, particularly in the data centers where companies are using third party servers, so they have no visibility or data on efficiency and cost savings that could be realized.

[4] Kathrin Winkler (EMC), Panel Discussion, "Moving Bits and Electrons: The Future of Energy efficient Data Centers & IT", Cleantech Forum, San Francisco, March 20, 2013.

[5] Nicole Peill-Moelter (Akamai), Panel Discussion, "Moving Bits and Electrons: The Future of Energy efficient Data Centers & IT", Cleantech Forum, San Francisco, March 20, 2013

Then there is the institutional barrier. In many cases, data center providers were paying at fixed cost – even if they were to save energy they wouldn't save any money. Now, that has changed by and large. But how the data centers pay for power is an example of institutional barrier that can have major impact on motivation to go green.

Data centers are becoming more sustainable than they have been. Overcoming above listed barriers and recognizing the central role they play in the big data growth, many data center providers are taking the lead in improving energy efficiency. Here are some of the best practices.

Shared Resources

Low utilization (7-15%) often results from dedicated resources. EMC, a global provider of IT services (including storage, cloud, big data and security), is running 60-80% utilization for its own operation because of dynamic configuration. They used to have separate HW and SW engineering labs at multiple locations in the company. Consolidating them into one data center with one virtual lab shared across the company has made the overall operation much more efficient. Actual physical infrastructure is also shared, thus resulting in much higher utilization.

Efficient Cloud Computing

Akamai launched its sustainability initiative for cloud computing in 2010. Technology is now allowing efficient geographically disperses architectures - software defined data centers compute where the data is instead of sucking data into where computing is. Promise of efficient cloud computing exists by using data centers where it is cold and efficient, e.g., data centers in Iceland, as long as the servers are connected to the world via high speed links.

A 2013 white paper, "The Power of Wireless Cloud" from Center for Energy Efficient Telecommunications (CEET) at University of Melbourne, Australia, analyses growing trends in wireless access technologies such as WiFi and 4G LTE, and concludes that wireless cloud will consume up to 43 TWh in 2015, compared to only 9.2 TWh in 2012, an increase of 460%. This is an increase in carbon footprint from 6 megatons of CO2 in 2012 to up to 30 megatons of CO2 in 2015, the equivalent of adding 4.9 million cars to the roads. Up to 90% of this consumption is attributable to wireless access network, and only 9% to data centers. With such rapid increase in wireless traffic, a major energy saving opportunity exists for telecom vendors by enabling efficient wireless access networks.

State-of-the-art Solutions

New data centers are being built with state-of-art solutions. But it is hard to make a radical change in existing build-out. New technologies are available, but many are not taking advantage of them. More aggressive ones such as EMC and Akamai have been able to make the transition and save on both energy and water.

Compliance as Opportunity

As the data center growth continues, do we expect any change in the way data centers are regulated? EPA is using compliance as well as positive incentives like ENERGY STAR® as tools to motivate data centers.

The big cloud computing and enterprise operations with their own data centers - Amazon, Apple, Google, Facebook, and Microsoft - have taken substantial action to go green.

For smaller enterprise data centers, however, the action taken varies from company to company and depends on the growth phase. Growing companies have motivation. But status quo companies have less motivation as energy is not that expensive. Small data centers are the scary part - unless you aggregate them, there is no business incentive to make them more efficient. Hence cloud-computing is the new hope for small businesses in becoming a part of energy efficient data center aggregation.

Data center operators want to be good corporate citizens and do want to reduce energy usage, but the primary change will happen only when direct business drivers or government regulations or both require it. They can do this directly in their own large data centers or by influencing the "Colo" partners.

6.4 Emergency Preparedness and Disaster Response

Superstorm Sandy was a major learning experience for telecom and data center infrastructure planners. While carriers are continuously looking to strengthen their DR program – Sandy provided an opportunity to fine-tune the ongoing efforts.

Verizon leveraged its backup diesel generators and built disaster recovery networks. The company's Network Operations Center (NOC) was in close communication with the NYC Mayor's sustainability office looking for real time data and providing localized support. The biggest impact was loss of commercial power. Although wire-line services were down, the wireless vehicles served as command centers. Still, availability of more real time data could have helped in dealing with the storm and managing it at the local level. A silver-lining is that Verizon is working diligently to create in downtown Manhattan the most robust fiber optic network in the world replacing copper plant to support NY stock exchange, and major financial institutions. Redundancy is built-in to the new network transmission and systems (fiber optic, 4G wireless).

Responding to Superstorm Sandy, AT&T, in partnership with T-Mobile, made monumental efforts to ensure that its customers had the best communications network possible and to try to minimize the communications problems for all people in the affected areas. It was a tremendous effort by its employees (many whose own families and homes were impacted by the storm), and partners who traveled far and worked tirelessly to restore service. The loss of backhaul transport was the single biggest issue that AT&T faced. Therefore the company's restoration efforts focused on rapidly deploying generators to areas that were without power but that still had the transport to carry customer communications.

Data centers already plan for disaster events to a large extent. Among large data center providers, such as Akamai, the network is highly distributed, highly redundant and vendor-wise. At any given time, 10% of the network could be off-line and it would not affect the overall operation. Data centers optimize by what the best available location is for a given customer, and if that is not available they shift to the next best available one. Dynamic mapping is used based on user demand, and by shifting overflows to nearby locations. Still, it can be highly disruptive when big events happen; for example when Sandy hit NYC, Akamai data center in lower Manhattan was flooded, but what made it even worse was that the back-up generators in the basement were also flooded resulting in a complete local outage. This did not cause catastrophic data loss, however. Thailand floods in 2011 took out disk-drive capacity in its supply chain and Akamai had to pay higher prices in order to get necessary materials.

7. Concluding Remarks

Population increase, economic growth, and climate change – the three major global change trends are inevitable. Sustainable growth requires green energy and a lot of infrastructure needs to be built around this. Sustainability is about long term, economic growth can't continue indefinitely if the major underlying issues and competing agendas are not addressed.

While natural gas appears to be a near term solution for energy independence in the US, the carbon issue is not going away with natural gas. Solving other problems, such as air and water pollution, is also daunting. In Canada and Japan, government agencies are serious about supporting renewables. Yet the Canadian Tar Sands oil and Keystone pipeline have been fiercely debated.

The European Union (EU) leaders have made a commitment to transform into a highly energy-efficient, low carbon economy. The EU has set itself targets for reducing its greenhouse gas emissions progressively up to 2050 and its member nations are working successfully towards meeting them. Yet the carbon trading system is broken in Europe.

Sustainability issues are quite complex in developing economies as strong economic growth is underway in many countries. And the developing world is not low carbon – their carbon footprint is now greater than that of the developed economies. China and India have built huge coal power fleets while pollution is continuing to rise in both countries. Renewables are also being pursued vigorously. China has made huge investments in the solar PV area and progress is taking place. India is pursuing solar and nuclear options.

International negotiations under the United Nations Framework Convention on Climate Change (UNFCCC) are underway to draw up a new global climate agreement to achieve greater cuts in global emissions over the rest of this decade. While the progress has been slow as further evidenced by the COP18 meeting in Doha, Qatar in Dec 2012, the new framework is targeted to be finalized by 2015 and implemented from 2020.

But, with atmospheric CO2 concentration already at 400 ppm and rising, climate change is happening now. So adaptation and resilience planning is a necessity while we continue to look

for mitigation solutions to limit further environmental degradation. In his book "Storms of my Grandchildren", Jim Hansen appealed to a sense of responsibility to the coming generations, and pointed out a need for urgent action.

On the other hand, projections indicate that there may not be enough resources to support 9.6 billion people by 2050 to live the way we live today. Water, food, steel, aluminum and other raw material – not just clean energy – could experience shortage. Innovation is needed for better ways of doing things - be much more efficient, and offer durable yet less resource intensive products (principally, water and energy). The challenge is to create and sell much more value.

The good news is that the human race is highly creative and extremely resilient. People are starting to see protection of critical natural resources as a choice. They are taking personal responsibilities about energy and water use. This will drive other choices as well – leading to a sustainable growth.

Figure 13. Innovation frontiers: preserve freshwater, generate clean electricity, and make efficient use of these two most critical resources.

8. Glossary

AGU	American Geophysical Union
CEET	Center for Energy Efficient Telecommunications
COP18	The eighteenth session of the Conference of the Parties of UNFCCC
CUE	Carbon Usage Efficiency. CUE is the ratio of total carbon emissions to IT system emissions.
DR	Disaster Response
EPA	Environmental Protection Agency
FCC	Federal Communications Commission
GEOSS	Global Earth Observation System of Systems
GHG	Greenhouse Gases
HDPE	High Density Polyethylene
HVAC	Heating, Ventilation, and Air-Conditioning
IPCC	Intergovernmental Panel on Climate Change
LTE	Long Term Evolution, marketed as 4G LTE
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NOC	Network Operations Center
NCA	National Climate Assessment
NYC	New York City
PUE	Power Usage Efficiency. PUE is the ratio of total power used to the power used by the IT system.
PV	Photovoltaic
UNFCCC	United Nations Framework Convention on Climate Change
USGCRP	United States Global Change Research Program
WUE	Water Usage Efficiency. The WUE measure is used to express the carbon cost of energy needed to extract and transport water.

About the Author

Shailendra Kumar is a technology and business executive with experience in significant leadership roles at Northrop Grumman, AT&T Bell Labs, and NASA-JPL, as well as in Silicon Valley startups. His career spans atmospheric sciences and space exploration, telecommunications and networking technologies, and information systems for energy and environment. He holds a PhD in Physics from the University of California, Berkeley and an MBA from UC Berkeley Haas School of Business and Columbia Business School.

Dr. Kumar co-chairs the Energy and Climate working group in the Federation of Earth Science Information Partners (ESIP) (http://www.esipfed.org). He recently coauthored the planning tools (decision support) chapter in the technical report for 2013 National Climate Assessment for the US Northeast.

ESIP is a collaboration of a number of groups, practitioners, and projects to manage, create tools, or consume Earth Science data, as well as folks who work with Earth Science educators. The ESIP Energy and Climate working group is addressing data and information needs at the nexus of energy, water and climate change. Historical discussions and other information can be found at the ESIP Energy and Climate wiki page:

http://wiki.esipfed.org/index.php/Energy_and_Climate

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