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Going Green without Ending Up in the Red: A Lesson in Clean Tech Safety

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The world is becoming smaller as globalization evolves. With the advent of the Internet, wireless telecom infrastructures, and social media, our planet is poised for rapid growth. With globalization comes the elevated consumption of natural resources. Increasing populations coupled with better health care and longer life expectancies will place a mounting strain on finite resources such as coal, crude oil, mined materials, and potable water.

According to The Clean Tech Group LLC, there are currently 18 megacities in the world. A megacity is defined as population of 10 million or more people. Of these 18 cities, only one third reside in the Western hemisphere. Now fast forward 40 years. There may be over 400 megacities if current growth rates remain the same. This will equate to a worldwide population of 10 billion humans, approximately 70% more then are on the earth today. Without sustainable practices, there may be widespread resource scarcity, which is tied to economic and national security instability.

The term ‘clean tech’ was introduced within the last 10 years in an effort to challenge the world to develop technologies, practices, and core fundamental values that center on the sustainable use of resources.

President Theodore Roosevelt recognized the need for sustainable practices over 100 years ago and was quoted as saying, “The nation behaves well if it treats its natural resources as assets which it must turn over to the next generation increased and not impaired in value.” [1] A similar concept comes from Native American folk lore, which states that we did not inherit the planet from our parents; we rent it from our children.

So what does clean tech look like? There are three key areas that represent this space. They are as follows:

Renewable Fuels & Power Generation	Efficiency, Control & Storage Technologies	Environmental Products & Resource Management
• Bio-fuel & bio renewables • Solar • Wind • Other • Services associated with the above	• Energy efficiency • Energy storage • Smart grid • Transportation	• Air • earth (soil) • Water (domestic and waste water) • Recycling

In other words, clean tech provides products and services to generate renewable power/fuel sources, allows for the more efficient use of resources, and creates technologies and services to mitigate our environmental impact. It is important to point out that there will most likely be no one clear winner hitting the sustainability “homerun,” but instead lots of competing and complementary products and services getting “singles and doubles” toward the common goal of improving sustainability and making our planet more resilient.

Are Green Jobs Safe Jobs?

When one thinks of green jobs, the tendency is to think that green jobs equate to clean jobs and thus they are also safe jobs. However, this is not the case, and there are common hazards as well as unique exposures that exist, whether in manufacturing, construction, or in the operation and maintenance of clean technologies.

OSHA recognized the safety challenges with the clean tech industry segment a few years ago and created the “Green Jobs” website http://www.osha.gov/dep/greenjobs/index.html

The Green Jobs website specifically looks at the safety and health aspects of the following sectors:

- Wind
- Solar
- Geothermal
- Biofuels
- Recycling
- Green roofs
- Hydrogen Fuel Cells
- Weather Insulation/Sealing

This white paper will focus on the safety aspects of Wind, Solar, Biomass/Biofuels and Batteries.

Solar Power Generation

Thomas Edison recognized the need for renewable energy over 100 years ago. He was quoted as saying, “I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait 'til oil and coal run out before we tackle that." [2]

As a level-set, there are two ways to harness power from the sun, photo voltaic (“PV”) or concentrating solar power (CSP) facilities. For the purposes of this whitepaper, we will focus on PV solar operations, as PV tends to be far more prevalent and widespread than CSP systems.

Know What You Are – Manufacturer, Installer, or Operator

When it comes to PV solar, you have to know what the company is specifically engaged in. Solar companies have varied business plans and each will have their own unique set of risks.

“Upstream” manufacturers of solar cells that use silicon-based substrates may have hazards similar to the semiconductor industry. Other cell manufacturers are engaged in thin film PV technologies that are going to have different potential concerns, such as toxic chemicals and nanotechnology.

"Midstream" manufacturers will assemble pre-made cells into panels. The predominant operations involve using large automated production lines to electromechanically assemble and wire the panels together using glass, metal, and other materials.

"Downstream" companies are engaged in the design and installation of solar PV systems. The systems can be ground-mounted or placed on roofs. The hazard profile shifts to more a construction-based set of risks, rather than manufacturing. Hence OSHA 1926 (construction) takes precedence over OSHA 1910 (general industry).

Finally there are the companies who own and operate these systems. In many cases the energy utilities or energy management companies are responsible for owning and operating the systems. In other cases, businesses and homeowners themselves buy the system as their own asset and operate it internally with the reward of collecting the "renewable energy credits" (RECs) and other tax incentives that are offered by the state and federal government.

New Jersey is a good case study in solar energy proliferation. While it's not the sunniest state in the nation, the RECs generated make it lucrative enough that NJ is the second leading solar state in the US. As with most clean tech products and services, it is these incentives, coupled with venture funding and government support, that are required for the industry to flourish.

The other thing to consider is the level of vertical integration associated with larger solar PV companies. Some companies will perform all upstream and midstream manufacturing and in a few cases also get involved with the system design and installation as a "turn key" solution. When this occurs, a wide array of hazards must be properly managed across the company's business units.

Solar Hazard Risk Continuum

The following discusses safety considerations when looking at the continuum of risk from a solar perspective. It is important to remember that each technology is unique to itself and specific hazards may or may not exist:

Silicon-Based PV Cell Manufacturers

Toxic gasses – There are 3 classes of gas as outlined by the Santa Clara County (California) Toxic Gas Ordinance (TGO)
http://www.stanford.edu/dept/EHS/prod/researchlab/lab/tgo/ord1998.pdf

Class 1 gasses are the most hazardous and require the utmost level of controls to prevent worker injury, as well as a chemical release to the public. Examples of class 1 gas include phosphine and arsine. If class 1 and 2 gasses are used in the manufacturing process, extensive worker safety and fire protection controls must be in place.

Toxic gas controls include formal risk assessments, toxic gas cabinets/bunkers (including sprinkler protection unless the gas is reactive with water), double wall gas delivery piping, gas detection with auto shut-off interlocks, inert gas purging, emergency and process scrubbers and backup power to keep the systems operational at all times. Gas cylinder handling is also paramount, as well as when cleaning and maintaining the semiconductor tools responsible for making the cells.

Flammable and pyrophoric gasses

While more common than toxic semiconductor gasses, adequate controls must still be implemented. Examples of these gasses include silane, hydrogen and ammonia. In many cases, chemical vapor deposition (CVD) or physical vapor deposition (PVD) tools are used to grow the silicon-based crystals, which brings its own unique set of thermal and ignition source hazards. These hazards need to have similar controls as toxic gasses, only not necessarily as robust. For example, double walled piping from cylinder to tool/furnace may not be required, but gas detection and interlocking the gas flow may still be necessary.

Wet benches

These are standalone benches that will hold a bath of liquid for cleaning, etching or masking purposes. The baths may be heated or may contain flammable liquids. Since many wet benches are made of plastic construction for corrosion resistance, there is a significant risk of the immersion heaters setting the plastic on fire if exposed without liquid. Typical controls for wet benches include temperature limit and low-level interlocks on the immersion heaters, sprinkler and/or fixed chemical protection over the bench and in the duct work, using plastic that meets FM 4910 flammability standards and preventing the use of hot plates, unless hardwired timers are installed on the hot plates.

Thin Film Solar Cell Manufacturers

Toxic chemicals – Like silicon based cell manufacturers, thin film cells may use semiconductor-like processes to apply coatings and dopants onto thin-film substrates. In addition to the CVD and PVD processes described earlier, a unique hazard stems from the manufacturing of Cadmium Telluride (CdTe) solar cells. The cadmium is toxic and carcinogenic, so proactive controls must be deigned into the system to segregate the worker from this significant occupational disease (OD) exposure. Formal risk assessments are critical when addressing toxic chemicals. The management of toxic chemicals is a strong example of when to use NIOSH's 'Prevention through Design' Methodology.

Nanotechnology – Some thin film inks and other materials use engineered nanoparticles in the 1-100 nm range. When these materials are used, the physical and chemical properties may change and not behave the same way as the macro-sized base material. There is concern for worker injury via inhalation, skin absorption and inadvertent ingestion. Therefore, if nanomaterials are being used, both a formal risk assessment process coupled with a control banding program should be in place. A control banding program is a consistent way to help ensure that unknown/emerging risks are properly addressed using best practice controls commercially available today.

Solar Panel Manufacturers

The companies that are involved in this type of operation tend to have electromechanical repetitive stress exposure, as well as acute material handling lifting issues once the panels become laminated with glass and other materials. Their size and bulkiness (e.g. 2' x 4' panels) can also make them awkward to manipulate. Panel manufacturers tend to use large, automated manufacturing equipment (laminators, pick and place assembly lines, etc.) that have machine guarding and lockout-tagout issues. Glass panels mishandling can also result in severe cuts/lacerations. Again, formal risk assessments are needed to ensure that the hierarchy of controls is commensurate with the risks.

Solar PV Installation

When addressing installation activities, the more traditional construction hazards exist. They include:

- Excavation/trenching
- Electrical (including lockout-tagout of equipment and physical contact with energized lines)
- Slips and falls (weather and/or housekeeping)
- Working from heights (e.g. on roofs)
- Material handling/lifting
- Hand tool RSI
- Heat and cold stress (especially when working on roofs)

A detailed, site specific contractor safety plan must be in place for each project and all subs must follow the plan. Provisions should be made in the contract that state failure to follow safety rules will result in workers being taken off the job. Additionally, the contract should also allow for financial penalties against the general contractor (GC) and subcontractors (subs) for workers who are safety offenders.

Solar PV Panel Cleaning

When PV solar arrays are in operation, an often overlooked issue is the cleaning of the panels. Dirty panels have less operating efficiency and thus the system does not perform optimally as designed. There will be several factors that increase or decrease cleaning schedules such as urban vs. rural locations, amount of exposure to birds and geologic activity. For example, in Hawaii airborne ash from active volcanic activities is a concern. Solar panels in Hawaii may need to be cleaned more frequently than in other parts of the world.

From a safety perspective, falls while cleaning are the obvious concern, whether having to reach the top of a ground-based array or when working on a roof-mounted system. Appropriate use of ladders, man-lifts and/or personal fall protection must be incorporated into the cleaning program. Additionally, if panel cleaning is contracted out, the appropriate insurance requirements and safety controls need to be spelled out contractually.

Solar PV Array Arc Fault Fires

An emerging issue has been noted with solar PV systems that has caused increased scrutiny for fire prevention. The issue has now been raised to a level where the National Electric Code and UL standards have been modified. The issue stems from several documented roof-mounted solar PV fires that have occurred in the US since the mid-2000s.

The issue occurs as follows:

- The United States uses grounded direct current PV systems. As a result, the system's ground leg is designed to have no current flowing on it. Most PV systems are protected from system short circuits with a combination of low amperage fuses (e.g. 5 amp) and high amperage fuses (e.g. 300 amp) that are placed between the PV panels and the inverter responsible for converting PV DC current to AC power for the grid tie-in.

- The problem starts when a small ground fault develops on the ground leg of the PV system. These faults can be caused by a variety of reasons such as improper installation, damaged wire insulation, rodents and thermal expansion.
    - The issue of thermal expansion is important to note because two of the most significant arc fault fires occurred during the spring and fall when there were significant temperature fluctuations between daytime and night.

- o Since these faults tend to be smaller than 5 amps, the fault can remain on the system indefinitely.
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- The problem becomes significant if a second fault develops on the DC side of the PV system, which results in a high temperature arc ensuing at the point of failure. The arc fault can bypasses the 5 amp fuses due to the second fault taking the path of least resistance. The arc can reach temperatures of 3000 degrees F. It is also important to remember that the PV power is "always on" as long as it's day light, so you simply can't shut the panels themselves off to remove DC current.
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- By the time the larger fuses react (upwards of 60 seconds potentially), the arc can catch surrounding combustible roofing material on fire.

In order to prevent this arc fault fire phenomenon from occurring, NEC 690.11 and UL 1699B were implemented in 2011 to prevent this hazard. NEC 690.5(A) also applies. Going forward, new solar PV installations will be required to have arc fault detection and protection installed. The easiest way to address arc fault protection for new projects is at the inverter, where integrated detection (ID) technology is designed into the inverter. With the advent of better DC radio frequency (RF) shielding, "false positive" PV fault system tripping has been greatly reduced. False trips were most common in the 1990s and early 2000s with prototype arc fault systems, particularly at first sunlight and at dusk.

For existing systems, it tends to be more costly to retrofit inverter-based detection-interlock devices. Therefore, a more viable option is to install differential current monitors (DCMs) between the panel array's combiner boxes and the inverter. This way, any ground fault in the milliamp range will be detected and the system can be shut down and investigated before a second fault and arcing condition occurs.

A less desirable way to detect latent arc faults is to test the PV system's DC ground leg at sun up and again at sun set every day to ensure there is no current flowing. In many cases, this may require the inspector to access the roof, placing them in danger of a fall. In order for this inspection program to be considered adequate, it must be formalized, documented and auditable.

In summary, when safety professionals perform solar PV array assessments for new or existing systems, arc fault controls need to be in place. A lack of protection or detection should be followed up with management and safety recommendations be submitted to address fault hazards.

Wind Turbines

From a global perspective, wind turbine projects are growing fast and furiously. Global installed wind power capacity is expected to more than double in the next five years, from 200 GW in 2010 to over 450 GW by year end 2015. China has been in a neck and neck race with the United States over the past two years; U.S. production just exceeded China at the end of 2011. [3]

The wind power industry is made up of many different players. These include:

- Component part suppliers that support the large, utility scale wind turbine Original Equipment Manufacturers" (OEMs)
- Innovative wind turbine manufacturers who makes turn-key wind turbine solutions
- Owners and operators of utility-scale wind farms

With thousands of component parts needing to work seamlessly with one another with a turbine system, manufacturing processes must be precise or wind turbine companies may find themselves plagued with mechanical failures or worse, face liability lawsuits.

Utility-Scale Turbines

Typically, those that support OEMs rely on the engineering requirements that the OEM provides. In most cases, the designs are turbine-specific. When vetting an OEM's contract proposal, the key consideration should be how well the component manufacturer's core competency aligns with what the OEM is requiring? For example, a large metal worker who traditionally fabricates parts for ships may have the appropriate skill set and facility to build the large flanges that bolt wind tower sections together.

Once a component manufacturer is in negotiations with the OEM, all correspondence regarding product specifications, performance expectations, etc. should be thoroughly documented and contractually agreed upon with the OEM's sign-off prior to production. Simple purchase orders may not be enough to protect component suppliers from liability, especially if property becomes damaged or people get injured.

In order to help ensure that component parts meet/exceed OEM specifications, the component manufacturer must have a robust quality control/quality assurance program to deliver what is being expected. Quality certifications such as ISO 9001 should be considered a starting point. Additionally, the component suppliers should have a business contingency plan in place in the event that natural or man-made events prevent them from making the parts as per their contract with the OEM.

Innovative Site-Specific Turbine Manufacturers

Over the past few years, there has been significant development in the smaller, site-specific 'turnkey' wind turbines. These units may be located on or near a building, or be found producing power for a farm or school. These smaller turbines can create safety and liability issues from things such as collapse, blades breaking and becoming projectiles or attractive nuisance from children/trespassers trying to access the turbine.

To help minimize the risk, the overall turbine design, as well as the specific component parts should go through a robust testing and quality assurance design process before they are commercialized and sold. Likewise, a comprehensive risk assessment process must be completed to determine where the turbines might be located, understand how they will be used, and evaluate the pathways for misuse, as well as people (or animals) who may come in contact with the turbine. Inspection and maintenance activities must also be contemplated when performing the risk assessment.

These innovative wind turbine manufacturers will often provide installation advice, or in some cases, may even act as the "paper general contractor" where the actual installation work is performed by a "hands-on" general contractor (GC) or by sub contractors under the manufacturer's control.

If installation design and construction is offered as part of the turnkey solution, the wind turbine manufacturer must protect itself from liability by having the appropriate contractual controls in place. For instance, the wind turbine manufacturer should consider requiring certificates of insurance with adequate limits for the project engineer, 'hands-on' general contractor, all subs underneath the GC and project/asset owner/landlord should and being named as an additional insured by the hands-on GC or all subs if the turbine manufacturer acts as the direct GC.

Likewise, the importance of indemnification agreements that contractually spell out who is responsible for what activities (during construction and ongoing once the project is complete and online) between the manufacturer, GC/subs and the project owner must be in place. A lack of contract management leads to unclear responsibilities for things as fundamental as contractor and maintenance staff safety requirements.

Addressing Wind Turbine Critical Risk Factors

Large, utility-scale wind turbine installations utilize well known and established technologies. However, the critical risk factor that continues to be a leading cause of loss stems from the weather. Lightning, excessive wind and ice throws must all be considered when contemplating safety factors into the component part designs. This is why it's so important to understand who is responsible for what throughout the turbine's lifecycle.

For example, contracts that rely on the component manufacturers to make engineering decisions on things like structural safety factors place far more accountability on 'the little guy'. This is why the proper indemnifications must be spelled out and component manufacturer should obtain signoff from the OEM before parts are produced. When it comes to the wind turbine innovator, it is expected that they will be assuming the responsibility for design work, unless spelled out contractually with their suppliers.

For utility-scale turbines OEMs have done a great job responding to weather related and structural fatigue-induced issues, police themselves with proven industry standards and use real-world testing facilities such as the Wind Turbine Testing Center in Boston, Massachusetts.

At the same time, improvements in the turbine's System Control and Data Acquisition (SCADA) intelligence found within the unit can help prevent the damage before it occurs. For example, on-board weather stations can shut the turbine down prior to the onset of high winds or during periods of icing. These SCADA systems can sense when ice is forming and can stop the turbine before ice throws occur. These improvements coupled with vigilance around maintenance and inspections will continue to help reduce the frequency and severity of incidents.

Future Technologies, Future Risk

Offshore wind farms and 'direct drive' turbine technologies are two other burgeoning areas of opportunity on the wind power segment's horizon. When it comes to offshore wind, there is tremendous potential to install projects as large as several hundred megawatts off of the U.S. coasts. Offshore farms are already established in other parts of the world like the Netherlands, Denmark and China. When dealing with these purpose-built turbines, the components must be designed and manufactured to an even a higher standard than onshore wind due to the corrosive salt atmosphere and the fact that inspections and maintenance are logistically more challenging to perform when the turbines are located miles off the coast.

Direct drive turbines create their electricity by generating a magnetic field without the need for complex gearboxes, which have historically been prone to failures. Direct drive technology is an important factor for growing offshore capacity. The challenge tends to come from the fact that direct drive designs are more unproven and that the components tend to be much larger, thus equating to more robust engineering and safety factor requirements.

Common Wind Turbine Hazards

Don't forget the obvious. The common hazards for wind turbines include:

- Falls
- Confined Spaces
- Fires
- Lockout-Tagout
- Medical and first aid
- Crane, Derrick and Hoist Safety
- Electrical
- Machine Guarding
- Respiratory protection

Regarding confined space exposure, the industry has responded to the entrapment issues by issuing rapid descent devices; however this is not standard in all cases. Communication can also be an issue within these units. Many Wind Farms are remote and do not have acceptable cell service. As a result, emergency responses can be delayed by the remote location and the communication issues.

Hot work operations also continue to be a major concern. An uncontrolled fire is a recipe for disaster. Adequate portable fire extinguishers must be available within the Nacelle during hot work operations. Moreover, a robust, documented and practiced hot work program must be in place to prevent loss of life and property. In most cases, the nacelles are not outfitted with fire protection.

Crane safety is another concern that can not be underestimated. Wind turbine cranes often work at heights in excess of 300 feet and are frequently moved over many miles within a single wind farm. With compressed schedules and related time constraints, the appropriate safety precautions must not be taken for granted. It is crucial to prevent the crane from hazards such as rollover, contact with overhead lines, etc. Short cuts can not be taken when the stakes are so high. The same holds true for personal fall protection as workers seldom get a second change to properly follow fall protection procedures.

Another concern that may be overlooked is the transportation of large wind turbine components to the site. Specialized rigging contractors must be used when the components are beyond the size and weight limitations of traditional freight haulers. In addition, the site must be prepared in such a manner that the riggers can deliver the components without the fear of rollover or other forms of site-induced damage. Poor weather conditions must also be factored in when working on the jobsite.

Biorenewables

Biorenewables is a broad class of business that encompasses biomass and biofuel facilities. Biomass can be any type of organic feedstock material that is used to make a renewable form of energy. These include; wood and wood products, grasses, waste material (rubbish), crops such as corn and sugar cane. Biofuels are essentially biomass facilities that instead of directly converting feedstock to energy will break down the feedstock down chemically into fuel. Typical biorenewable products include ethanol, biodiesel, waxes, polymers, methane (from landfills) and gasified biomass material.

Biorenewable companies can run the gamut from using older, more established energy/fuel processes to methods that focus on innovative, unproven technology. As with most renewable energy sources, biorenewables become more attractive to produce when the cost of traditional energy increases.

Biofuels

Ethanol production is an older technology that has progressed incrementally over time. The traditional corn ethanol plants are gaining efficiencies and improving on their yields, while focusing on lowering costs. Cellulosic ‘second generation’ ethanol is in the development stage and working towards commercialization.

Biodiesel fuel production is traditionally the conversion of extracted oils into fuels. These oils can be extracted from plants or recycled from rendered animals or from used cooking and other oils. The conversion processes may involve chemicals that are hazardous and toxic.

BioEnergy

Biomass operations tend to consist of wood and trash burning facilities that use the heat of combustion to convert water into steam to power turbines. These plants have been around for generations. While there are some new plants, in many cases, the biomass plants you will see are older units that are now being brought back on line under a state’s renewable portfolio standard (RPS). These plants may also be exploring the use of alternative fuel consumption practices, such as the inclusion of a variety of waste products to supplement their more traditional feedstock sources.

Biogas Processes

Methane generation operations range from methane gas recovery (via decaying organic landfill material) to methane harvesting using a digesting process that breaks down waste material from cattle and feed lots. There has been significant refinement of the landfill-based technology, making it not only more reliable but cost competitive. However, some manufacturers of these biogas systems may not be familiar with the nuances of power generation and may lack the controls to prevent an accident or fire.

The last area of technology discussed is the conversion of organic raw or waste products to energy through processes such as gasification and calcination. While these are not new technologies, they are among the more dangerous methods of biomass conversion used. In simple terms, the organic material is subject to heat at, near or above its auto ignition temperatures while in a controlled atmosphere, normally with reduced oxygen content. This causes the material to thermally breakdown via pyrolysis. One of the primary concerns with these reduction processes is the control of the inputs. An uncontrolled change in pressure, oxygen level or temperature can result in an explosion with devastating results.

Biorenewable Hazards

The common hazards associated with biorenewables include:

- Fire and Explosions
- Chemical reactivity
- Toxicity
- Confined spaces

Within the biorenewable space, key control factors include:

- Fully commissioning any biorenewable project throughout the design, construction and operational life cycle
- Verifying that the equipment is designed for its use and service

- Verifying that the equipment meets the appropriate standards
- Determining if the control levels are adequate to prevent an upset
- Waste and by-product handling and management
- Emissions control
- Feedstock management, including contractual controls for hazards
  - -Special controls for biological, hazardous materials
  - -Radiation detection where necessary.

Battery Energy Solutions

In order to sustain a reliable source of renewable energy from solar and wind, there must be a way to capture and store electricity when the sun isn't shining and the wind isn't blowing. Electrical grids are based on the premise of energy stability, producing 60 htz of electrical power continuously. Electrical utilities that become too reliant on solar and wind energy run the risk of grid instability unless a robust network of energy storage solutions can supplement the power when necessary.

Another advent of electrical storage technology is the rise of hybrid and 'plug-in' electric vehicles (EV) into the consumer marketplace. Both President Barack Obama and Department of Energy Secretary Steven Chu have pledged to have one million EVs on US roadways by 2015. [4]

Traditionally, lead-acid batteries have been the industry standard, with deep cycle batteries being used for applications such as energy storage and distribution. Lead-acid batteries are cost effective, reliable, and rechargeable and do their job well. However, they are large and heavy when considering their power-to-weight ratio and there are environmental and safety concerns. For example, when there is a large concentration of lead-acid batteries, as in a utility storage system or data center, there is the potential for hydrogen off-gassing that can relate to an explosion. As a result, appropriate hydrogen monitoring and venting must be in place.

Battery manufacturers have been looking for alternative sources that achieve better power to weight ratios. A popular battery type that emerged in the 20th century was the nickel cadmium of "Nicad" battery. Nicads work well but can have challenging health, safety, temperature sensitivity, and disposal concerns. Among the biggest of these concerns is the use of cadmium, a toxic and carcinogenic metal. Nickel Metal Hydride (NiMH) evolved from Nicads, using similar technology but with a less toxic profile. However, NiMH tends to have poorer energy discharge characteristics when compared to Nicad batteries.

Lithium batteries had the promise to become a disruptive technology due to its tremendous power to weight density ratio. The downside however is that pure lithium-based batteries were highly reactive and burn extremely hot if they short out and catch fire. Lithium batteries are also very challenging to manufacture. If the lithium comes in contact with water or humid air conditions, it can cause a pyrophoric chain reaction and fire. Pure lithium batteries are manufactured today but tend to be used where power density is more important than its safety profile. Therefore, these batteries tend to be used for military/defense applications where they will not be in the hands of public consumers.

Battery manufacturers recognized the benefits of lithium, but needed to negate the risks. The result was the creation of lithium-ion (li-ion) batteries that use a lithiated chemical compound to stabilize the lithium runaway energy potential. Lithium ion batteries are made up of various anode, cathode and electrolyte chemistries. Some of these chemistries can produce more power or allow for more charging cycles, while other battery chemistries are inherently safer, but may suffer in performance.   The most successful lithium ion manufacturers are the ones who can strike the balance between performance, charging characteristics, longevity and safety.

While lithium ion batteries have less volatility than their pure lithium cousins, they can still cause fires under certain conditions during manufacturing, in storage, transit and during use. Therefore, the appropriate facilities, processes and quality practices must be in place to mitigate loss potential. Nearly all lithium ion batteries that are rechargeable, (which are referred to as secondary batteries), have active battery management circuitry built into the batteries to help ensure that charging and discharging is appropriate with no faults or shorts.

In summary, lithium ion battery manufacturers must take a holistic approach throughout the product's lifecycle from design to manufacture to distribution to product use/misuse and finally to product disposal including 'second life' applications and end of life recycling opportunities.

Conclusion

Clean tech and green jobs go hand in hand. Green jobs are important to our economic future, as well as mitigating our dependence on fossil fuels. Clean tech also brings the promise of increased operational efficiencies, with the end-game of protecting our natural resources.

Green jobs are not necessarily safe jobs and robust safety practices must be exercised throughout the clean tech continuum. Therefore, the opportunities are burgeoning for the safety professional, as clean tech spans many industry segments such as energy, technology, commercial manufacturing and life sciences. Incorporating robust risk assessment behaviors within these companies is what will separate the pretenders from the contenders. Those who strive to be sustainable in this marketplace are the ones who incorporate safety into their clean tech ecosystem.

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