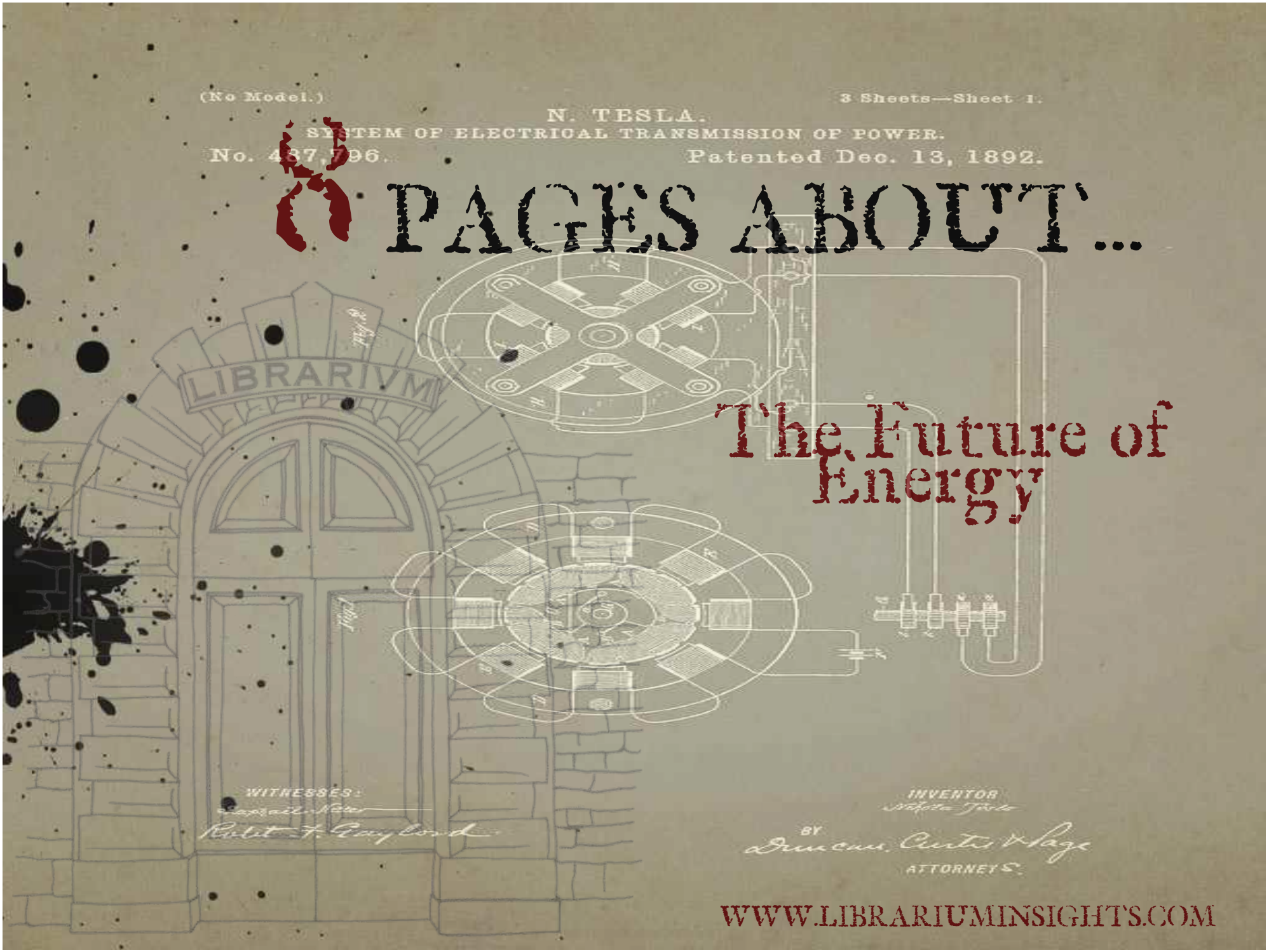

8 PAGES ABOUT...

The Future of Energy

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ABOUT OUR '8 PAGES' SERIES:

The Librarium Associates monthly '8 Pages About..' series is a publication created by our team focused on topical current issues that we feel warrants a deep dive were we can distill the key developments and provide an alternative view on such topics.

We are constantly engaged in active horizon scanning while adhering to our belief that students of the lessons of history and permanent features such as geographic realities can provide superior insights.

From these broad scenarios we work to identify investable trends and specific opportunities. We find that such a broad approach provides an 'early alarm' system for risk management and an indicator of attractive price/value situations across asset classes.

The intention of our research and the basic premise of this publication is to present rational perspectives based upon a diligent analysis of historical data. Through organizing the data logically, information is created. Through understanding and developing perspectives on the information, knowledge is generated. With knowledge, one can then start to make informed decisions.

The most practical way to imagine the future is to question the expected, this is best done making use of what we call 'critical thinking' – Critical thinking is the careful, deliberate determination of whether one should accept, reject or suspend judgment about a claim and the degree of confidence with which one accepts or rejects it. Critical thinking employs not only logic but a broad intellectual criteria such as the one outlined above. Critical thinking requires extensive experience in identifying the extent of one's own ignorance in a wide variety of subjects which is often captured in the following sentence: I thought I knew, but I merely believed.

As J.F. Kennedy put it: "Belief in myths allows the comfort of opinion without the discomfort of thought." Our aim is always to avoid this trap of the mind, when one attempts to look into the future one is better of exhibiting a more intellectually humble approach and challenge one's beliefs and opinions by asking the question: What if we took the opposite view? This leads to a more balanced set of insights in our view.

The insights and opinions offered in this document are meant as a summary of events and our views – not a conclusive or exhaustive overview or for that matter a specific investment recommendation.

We hope it will offer some food for thought and that it can form the basis of conversations between our clients, interested parties and ourselves.

Sincerely yours,

Mr. S.H. Sorensen
Senior Associate

SOMETHING IS AFOOT IN THE GLOBAL ENERGY MIX...

Today, fossil fuels produce the majority of the world's energy, but renewable energy is starting to make significant inroads. It already provides 20% of our electricity mix, with solar installations, wind farms and hydroelectric plants making major contributions. Researchers, engineers and smart companies are already looking at ways to improve the amount of energy we can harvest from established renewable energy technologies to meet the ever-increasing demands for power by increasing efficiencies, reassessing distribution grids and developing storage facilities.

Technology is affecting the energy markets dramatically – it always have, from Colonel Drake's "radical idea" to drill for oil, to the use of so-called fracking methods for the unleashing of the US shale oil & gas – and this impact is growing exponentially. The pattern-seeking human mind is built for an observable linear universe, but has cognitive difficulty recognizing and understanding the impact of exponential growth. Paralleling Moore's Law, the current growth rate of new technologies roughly doubles every two years. In transportation, the global penetration rate of electric vehicles or EVs, was 1% at the end of 2016 and now is probably 1.5%. However, a doubling every two years of this level of usage would lead to an automobile market that primarily consists of EVs in approximately 12 years, reducing gasoline demand and international oil revenues to a degree that today would seem unfathomable to the linear-thinking mind.

Renewable energy sources such as solar and wind are well into their exponential growth curves and are even ahead of EVs in this regard. Based on current growth curves for other recent technologies and due to similar growth rates in battery technology and pricing, it is likely that solar power will supplant its fossil fuel rivals in the near future. Something dramatic is clearly afoot in the global energy mix, investors need to be one step ahead of the path of progress in order to avoid being on the wrong side of events and to harness the spectacular gains that such changes will unleash for the companies that develops the technological solutions that enables this ongoing transformation to leap.

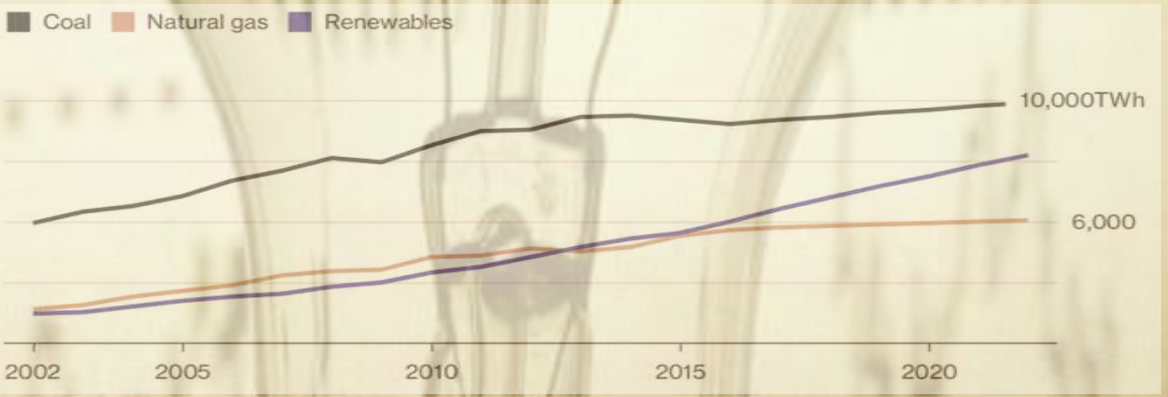
"Solar, wind & water is set to produce 57% of global energy by 2050." – Science Direct

ELECTRIC AVENUE

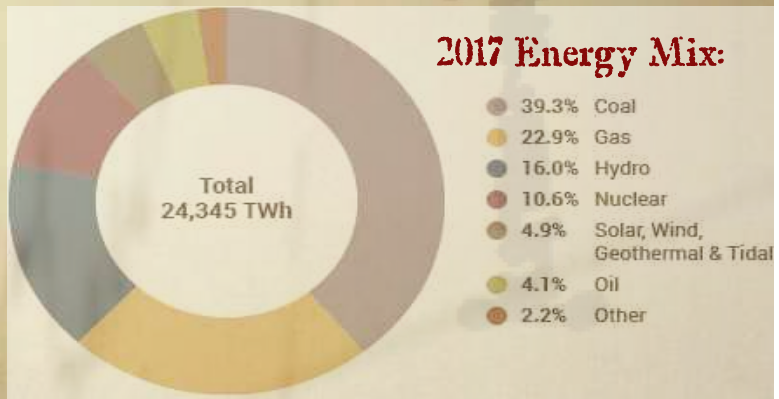
If the future is electric, the path leads to renewable energy and nuclear. A recent Bloomberg New Energy Finance (BNEF) study of comparative costs worldwide shows an 18% improvement in the competitiveness of onshore wind and solar in the last year and new and rapidly developing roles for batteries. Coal and even natural gas are facing a mounting threat to their position in the world's electricity generation mix, as a result of the spectacular reductions in cost not just for wind and solar technologies, but also batteries.

The BNEF report highlights the so-called 'levelized costs of electricity' or LCOE, for all the leading technologies and finds that fossil fuel power is facing an unprecedented challenge in all three roles it performs in the energy mix - the supply of 'bulk generation,' the supply of 'dispatchable generation,' and the provision of 'flexibility.' **The path forward is the electric avenue, but how will we get sufficient low-cost supply?** Some of the solutions will be discussed in this report along with how investors can best position to harness these powerful dynamics.

RENEWABLES RISING...



Note: TWh = terawatt-hours Sources: International Energy Agency, Bloomberg New Energy Finance.



THE POWER OF THE WIND

Since a breeze set the blades of the world's first electricity-generating wind turbines spinning in the late 19th century, the technology of wind power has undergone tremendous transformations. Turbine towers now tower high to allow incredibly long blades to extract more and more energy from the restless skies. Gigantic wind turbine farms on both land and sea now account for about 3% of the world's energy production - a figure that's set to soar as new types of wind turbines find better ways to unlock this endless source of clean power.

Planet Earth's atmosphere is so charged with restless energy that, in theory at least, sufficiently harnessed wind power would be able to supply all of mankind with of its energy needs – forever. Ken Caldeira, a climate scientist at Stanford University with big ideas, reckons that "The total amount of power in winds globally is something like 50 times bigger that the total amount of power used by human civilization. If we were to power civilization by winds, we would need to capture about 2% of winds today." Mr. Caldeira is not alone in seeing the amazing potential of wind power, all around the world many brilliant minds and innovative companies are engaged in the pursuit of better and better technology to effectively harness this enormous bounty. Worldwide production of wind energy continues to double every 5 years. Every day, up to 100 new wind turbines are erected all over the globe. The advantages are clear, wind is a common and free resource that no country can lay claim to or control. Wind farms can be constructed quicker and often more cheaply than fossil-fuels power stations. Their construction and continued use creates far less pollution. And of course wind is a resource that will never ever run out.

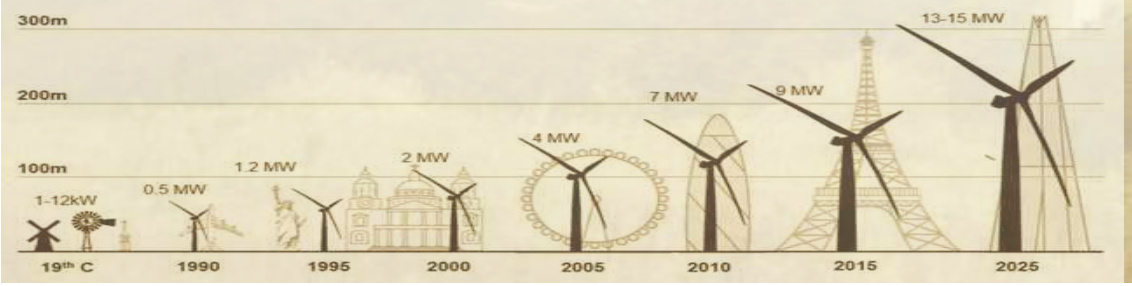
A global whirlwind of change...

Until 10 years ago, wind was primarily a European energy source, but in recent years, the US and China have been embracing wind energy. In 2015, China overtook Europe, increasing its production by 30 GW in one year. Although the country has yet to develop its own world-class technologies of its own, the growing number of Chinese wind turbine manufacturers suggests that this will happen over the coming years. Latin America is also starting to reap the benefit of wind power, with Brazil in particular investing in wind farms. A large part of Brazil's energy production comes from hydropower, but recent droughts have highlighted the shortfalls in this approach – a phenomenon not unique to Brazil but a worldwide concern.

The challenges to overcome...

All countries face the most obvious drawback to wind energy – no wind means no power. The wind may be an endlessly renewable source of power but it's a fickle one, meaning that technology needs to address the transport and storage of power as well as its production. An important factor for the future of wind energy is therefore grids and storage – which we look at broadly later in this report – as well as the international exchange of energy. A network already exists in Scandinavia to transfer electricity further afield when there's overproduction and switch to hydropower when the wind stops blowing. Several similar solutions linking wind and solar plants across Southern Europe and in China are also being considered, ensuring that none of the captured power is going to waste. As renewable energy is a technology, and not something finite that we dig up and burn, it will continue to expand and become more effective and efficient.

The Evolution of wind turbine heights & output...



"On 2 occasions, I've argued that we couldn't possibly build a more efficient turbine but we have built them. So now I've stopped being so sure."
– Mr. Stiesdal, Chief of Technology, Siemens.

A LOOK TO THE FUTURE:

TODAY:

The world's largest wind turbine has a capacity of 8 MW. Wind turbine manufacturers are working to build a wind turbine with a capacity of 10 MW. As well as more cost efficient floating solutions for the fast growing offshore space and the world's first flying windmill – Altaero's Buoyant Airborne Turbine – has been launched over Alaska as a test for a supply solution for remote communities as well as with a view to trial technology for the future ambition to build solutions that can harness the stronger, more predictable winds at higher altitudes.

2035:

The standard wind turbines now all have a capacity of 10 MW. Wind accounts for 15% of world energy production. New types of wind turbines are developed as an integrated move towards better efficiencies and environmental solutions. The size of turbines and the offshore farms have increased significantly along with integrated smart grid, distribution and storage solutions.

2050:

Offshore wind farms have become huge, with 50 MW turbines several hundred meters tall now the norm. Experimental tethered wind turbines now hang in the sky, floating around far above the Earth's surface where the wind blows constantly and at high speeds with an aim to develop technology that would enable us to harness the mighty Jet stream. Regional smart grids move energy around in a highly efficient framework.

Illustration Source: BNEF

POWERED BY THE SUN

Earth's largest renewable energy source is a huge power plant millions of kilometers away. In just one hour, the Sun emits enough energy to meet the Earth's annual energy consumption. Solar energy is already an important part of the energy mix and in the future it will become even more important, as building facades and even roads start to harvest the Sun's rays before adding this energy to the grid. But before the Sun can power our world, researchers and companies need to develop new materials and technologies to use in cheaper and more efficient solar cells. With the principles of Moore's Law in full effect we will no doubt continue to rapidly expand our solutions in this attractive space.

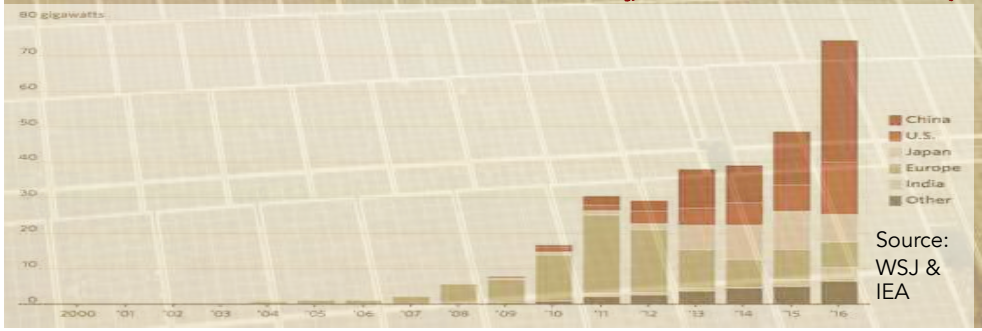
A global appetite for the power of the Sun...

In 2016, according to the IEA, solar power grew faster than any other source for the first time and is set to dominate renewable technologies for years to come. 165 gigawatts of renewables were completed in 2017, which was two-thirds of the net expansion in global electricity supply. Solar powered by photovoltaics, or PVs, grew by 50%, with almost half of new plants built in China. The EIA expect that solar PV capacity will be higher than any other renewable technology through 2022. China has been the leader in manufacturing for a long time, what is new is the share in the market as a consumer. In 2017 it was the equivalent to the total installed capacity of PV in Germany, who has been a leader in the space for over a decade. The US and India are among other nations pushing renewables. They along with China are projected to make up two-thirds of the clean-energy expansion worldwide. Despite President Trump's vow to bolster coal's position in the power market, the US is expected to be the 2nd largest market for renewables. The economic case is increasingly becoming undeniable.

An energy bounty bigger than mankind needs...

The energy in sunlight that strikes the Earth's surface each day is equivalent to 120,000 terrawatts (TW). In 2020, energy needs on Earth is forecast to be 20 TW each day meaning that the Earth receives 6,000 times more energy from the Sun than we can use. However today's solar cells convert only between 10% and 35% of the solar energy into electricity, so there's a massive opportunity to improve our technology and make it more efficient. As the technology has evolved since 1883, when Charles Fritts designed the first solar cell, we have seen incredible advances and a dramatic reduction in costs already. This is only set to continue as we experiment with new materials such as graphene, new technologies and new formats – both in PVs and in large scale Concentrated Solar Energy (CSE) projects. CSE projects - such as the world's current largest plant in California, with its 173,500 mirrors sending enough sunlight into three solar towers, to Morocco's impressive Noor installation, which currently covers an area of 25 km2 on the edge of the Sahara desert and is set to be the world's largest solar power plant at least until the Saudi Arabian vision for a $200bln 300-megawatt plant becomes a reality - holds much promise with the benefits of scale and energy storage built into the technology. By 2050 it's hoped that solar cells will be 65% cheaper than they are today. Heavy users of energy, such as China and the US, are researching new materials to use in CSE plants. And they are also looking at alternative materials that can replace silicon in conventional solar panels. With graphene looking like the most likely replacement due to it's inherently superior qualities and its low cost compared to other rare earth elements such as indium, tellurium and gallium which are all more effective but expensive.

Solar power takes off – Annual net additions to global solar panels capacity:



Source: WSJ & IEA

"If 0.16% of the Earth's surface was covered with solar panels, the planet's annual energy needs would be met by a single hour of cloud-free sunshine."
– Mr. Green, Prof. University of New South Wales.

A LOOK TO THE FUTURE...

TODAY:

Solar cells assembled in large solar power plants can supply nearby cities with power. Local solutions with integrated micro grids and storage power industrial hubs and whole regions in many isolated parts of the world such as the Pacific archipelago, Tokelau and in parts of Australia. Initial pilot projects for so-called smart solar roads, that can harvest energy from the sun and recharge vehicles while they are moving has been launched in China with more conventional approaches being tested in Europe and the US. A solar-powered aircraft has circulated the Earth and satellites have been harvesting the uninterrupted sunshine in space since 1958. Buildings are beginning to be constructed with fully integrated PV systems offsetting significant parts of their energy needs.

2035:

Our smaller electronic devices, such as mobile phones, will increasingly be powered directly from the sun. Solar roads will be commonplace as will integrated PV's in new buildings. Improvements in storage and smart grids will mean that solar is a large part of the energy mix – both night and day.

2050:

Mass-produced vehicles such as cars, busses, boats and trains that run on pure solar energy are now widespread as the efficiency of our PV technology has advanced dramatically. Most roads and industrial installations have integrated PVs and residential and office buildings derive most of their energy directly from their own built-in solar panels.

THE POWER OF WATER

Fast-moving Norwegian rapids, gushing Chinese rivers and giant South American waterfalls are all huge deposits of kinetic energy, which can be turned into electricity. In its simplest form, hydropower requires only a turbine. When the flowing water turns the turbine's blades, the mechanical energy this produces can be used to drive a generator and make electricity. In the future, hydropower will also be extracted from machines floating in the sea or standing on the ocean floor. These will harvest power from ocean currents and tidal movements.

The world's oldest form of energy...

Putting gushing water's energy to work is not a new idea. The remains of water wheels dating from 300 BC have been found in both Greece and China. Other research shows how water mills have powered milling, grinding and hammering since antiquity. Before the steam engine was invented, the mechanical force from water turbines was used in factories to spin cotton or power sewing machines, for example. Then during the 19th century, engineers discovered that water's kinetic energy could be converted into electricity. The first hydroelectric power plants were built in the 1880s at Niagara Falls in the US. At this time, the electricity for large parts of New York State was almost wholly provided by hydropower. A quarter of a century later, the Chinese built their first major hydroelectric plant, which had a capacity of 500kW – impressive for its time, but nothing compared to, for example, the Three Gorges Dam, which currently has a capacity of 22.5 GW. Essentially, these early systems employed the same methods as hydroelectric power stations use today. There are 3 main types of hydropower plants:

Run-of-the-river plants, the water is led through a pipe into turbine that converts the kinetic energy into electricity. Run-of-the-river plants are not a reliable source of energy, because the amount of electricity generated depends on the amount of water in the river. At dry times of the year, they produce less electricity. However, these power plants can be made more effective by, for example, running the water through a cascade of small ponds. Here, it's stored at night, when electricity demand is low, and then run through the plant during the day when consumption is high.

In reservoir power stations, dams gather large amounts of water from rivers in giant pools. This gives the water a larger and more powerful drop. The water can be kept in the reservoir for long periods and sluiced through the dam's turbines channels only when the need for energy arises. At times of year when the rivers typically contain more water, the basins store extra supplies. Conversely, at more arid times of the year, the hydropower plant can use the store of dammed water to produce the power needed.

Hydropower can also be produced by lakes and other areas with plenty of water. However, because of the lack of water flow, pumped storage plants rely on two pools: one low-lying basin and one above it. The water is conveyed in a cycle where it runs through the turbines down to the lower-lying basin. It's then pumped back up to the higher pool. To pump the water back costs energy, however. In the past, excess electricity was used to pump the water up when grid demand was low. When demand increased, the water could then be passed down through the turbines again. In this way, pumping storage plants acted as an energy store. Today, pumping plants exploit other green energy sources such as wind. On windy days, excess wind energy is used to pump water back to the top basin. This is a method of storing wind energy that would otherwise go to waste because it is difficult to store.

Hydroelectric plants with pumping stations and dams are huge projects and expensive to build. China's Three Gorges Dam is the country's largest cement structure, at 200 meters high and 2,335 meters long with a capacity of 22,500MW it can provide 9 of China's 23 provinces with electricity, including China's most populous city, Shanghai. Though the initial costs are high the advantages of hydroelectric plants are clear, once the initial construction phase is over, the operational and "input" costs are far cheaper than with all other energy technologies. As a result hydropower currently supplies about 16% of total global electricity consumption and it's the most widely used form of renewable energy in the world.

Catching the wave...

The sea's waves and tides contain a huge amount of power. Scientists believe that the kinetic energy of water is 800 times greater than wind. Over the past 20 years researchers have been working to crack the code of how to harvest energy from the sea in the most efficient and durable manner. Thanks to a combination of the differentials between areas of high pressure and low pressure, and the Earth's rotation, waves constantly roll across the oceans. As with rivers, the energy of waves can be harvested. Wave power is particularly interesting for costal communities, located away from the traditional grid and distribution infrastructure, where a micro-grid solution can be established tailored for the community's specific requirements. In addition, tidal power plants look set to become increasingly important in the future. The optimal version is likely to be large-scale facilities that dam the tide and direct it through channels fitted with turbines.

A LOOK TO THE FUTURE:

TODAY:

16% of global electric energy consumption is provided by hydropower technologies. Hydropower is widely used globally with 159 countries getting a significant part of their energy supply from this enduring source. Beyond traditional technologies, experiments in wave and tidal based solutions are in progress and technologies are being improved.

2035:

'Wind farms' at the bottom of the sea use tidal currents to produce electricity on a large scale. Underwater turbines capture energy from tidal shifts between high and low tide. Micro-grids based on hybrids of renewable energy sources are common on islands and in remote costal communities.

2050:

By 2050 the amount of electricity produced by hydropower will double to 2,000 GW, according to the IEA. This comes from a large increase in large scale wave and tide installations drawing on decades of advances in technologies. Technology begets more technology and advances are likely to have been realized in areas that are minute today, but leaps could have occurred with advances in materials, such as membranes for salt-powered turbines.

800 TIME GREATER. THAT'S THE COMPARISON BETWEEN THE KINETIC ENERGY OF THE WATER AND WIND ACCORDING TO RESEARCHERS.

THE NUCLEAR OPTION:

Nuclear power took a major step back after the biggest nuclear catastrophe since Chernobyl took place in Fukushima, but that does not mean existing Generation III projects (the Fukushima reactor is a Gen II) are not viable and safe. In fact during the last 30 years engineers have improved reactor safety considerably. The newest designs, called Generation III+, are just beginning to come online. Generation I plants were early prototypes; Generation II's were built from the 1960s to the 1990s and include the facility at Fukushima; and Generation III's began operating in the late 1990s, though primarily in Japan, France and Russia. Unlike their predecessors, most Generation III+ reactors have layers of passive safety elements designed to stave off a meltdown, even in the event of power loss. Construction of the first Generation III+ reactors is well under way in Europe, with Finland and France at the forefront. While most other advanced economies are slowly pivoting to energy sources like natural gas, solar and wind, China's soaring energy demand means it's spending billions on new power plants across the energy spectrum, from coal and natural gas, to renewables and nuclear. China has the world's most aggressive reactor construction plan, with the goal of boosting its nuclear power capacity by about 70 percent to 58 gigawatts by 2020. China is becoming the testing ground for a new breed of nuclear power stations designed to be safer and cheaper, as scientists from the U.S. and other Western nations find it difficult to raise enough money to build experimental plants at home. Japan's companies are another source of real innovation in the space with a strong focus on safety.

Thor Vs. Pluto...

In the beginning, nuclear scientists identified two fuel sources for the atomic age; uranium and thorium. They went with uranium. Why? It was not because uranium was the better fuel. Thorium is more abundant. It is simpler. It is safer. But thorium had one strategic disadvantage; You could not make plutonium from it. During the Cold War, the science goal was synonymous with the military goal; nuclear weapons. Thorium could not compete in this environment. A Swedish chemist named Jons Jakob Berzelius discovered thorium in 1828 and named it after Thor, the god of thunder in Norse mythology – and incidentally believed to be the guardian of mankind. American physicists Edwin McMillan and Glenn Seaborg invented "synthesized" plutonium in 1940 and named it after Pluto, the god of hell in Greek mythology. As a metaphor of moral choice in the dawning of the atomic age, the opposing fuels – Thor vs. Pluto – could not have been more exquisitely named.

Even with their significant safety improvements, Generation III+ plants can, theoretically, melt down. Some people within the nuclear industry are calling for the implementation of still newer reactor designs, collectively called Generation IV. The thorium-powered molten-salt reactor (MSR) is one such design. In an MSR, liquid thorium would replace the solid uranium fuel used in today's plants, a change that would make meltdowns all but impossible. MSRs where first developed at Tennessee's Oak Ridge National Laboratory in the early 1960s and ran for a total of 22,000 hours between 1965 and 1969. Of the handful of Generation IV reactor designs circulating today, only the MSR has been proven outside computer models. The MSR design has two primary safety advantages. Its liquid fuel remains at much lower pressures than the solid fuel in light-water plants. This greatly decreases the likelihood of an accident, such as the one at Fukushima. Further, in the event of a power outage, a frozen salt plug within the reactor melts and the liquid fuel passively drains into tanks where it solidifies, stopping the fission reaction.

In addition to safety, thorium power provides other strategic benefits; without the need for large cooling towers, MSRs can be much smaller than typical light-water plants, both physically and in power capacity. Today's average nuclear power plant generates around 1,000 megawatts. A thorium-fueled MSR might generate as little as 50 megawatts. Smaller, more numerous plants could save on transmission loss (which can be up to 30 percent on the present grid). The U.S. Army has shown an interest in using MSRs to power individual bases and Google, which relies on steady power to keep its servers running, held a conference on thorium reactors last year during which the innovative company indicated that they would be interested in having a 70- or 80-megawatt reactor sitting next door to a data center.

Canada has been developing thorium power for decades and is currently the leading nation in this field. However, China has shown a strong interest in the technology due to the safety factors and good economics of thorium over uranium. India is also showing strong interest in these developments as they have a gigantic need for reliable low-cost energy supply, as their population is set to overtake China's in the decade ahead. India has huge resources of easily accessible thorium and relatively little uranium and as a result has recently made large-scale production a major goal in its nuclear program along with building out the technology over the next 15-20 years. Updated models of uranium-fueled power plants are struggling mightily to get off the ground in the US, several start-up companies are exploring molten-salt reactors, including the visionary Mr. Kirk Sorensen (No relation to the Author) who you must watch for an insightful overview: https://www.ted.com/talks/kirk_sorensen_thorium_an_alternative_nuclear_fuel As with standard nuclear, China is again charging ahead in the thorium-based reactor space. They have plans beyond the test and development phase, including having one hooked up to the grid inside the next 15 years. If we see a real push in this space, and thorium lives up to its potential, we should see a great and safer future for nuclear power.

"Imagine a form of nuclear energy with greater output and virtually no safety issues. We have good line of sight on the science to build one." – Kirk Sorensen, Former NASA Scientist.

A LOOK TO THE FUTURE:

TODAY:

New nuclear power plants are being built. The plants still run on uranium, but they are safer and use fuel more efficiently. Researchers around the world are carrying out experiments with fusion reactors.

2035:

Thorium begins to be used as a fuel in nuclear plants. Fusion facility have shown that hydrogen fusion can produce more energy than the amount of energy that starts the process. Finland and Sweden begin the long-term storage of highly radioactive waste.

2050:

The first fusion power plants are ready for use. The amounts of highly radioactive waste is minimized in molten salt reactors. Several countries have stored their highly radioactive wastes.

THE QUEST TO STORE AND DISTRIBUTE THE ENERGY EFFICIENTLY:

The smart grid...

As discussed throughout this report we can derive the power required for all our needs, including all-electric transportation, from renewable energy sources many time over and with advances in nuclear technology we could add safe and reliable supply with reduced environmental consequences where needed. The challenge and opportunity at hand, beyond the continued development of all these technologies, is how to combine them into a global network of smart grids built for the future including storage options to offset the intermittent nature of most renewable options. Electrification, decentralization and digitalization are all converging to create a smarter and more connected electric system that promises to increase reliability, security, environmental sustainability and asset utilization, while opening new opportunities for utility companies and investors.

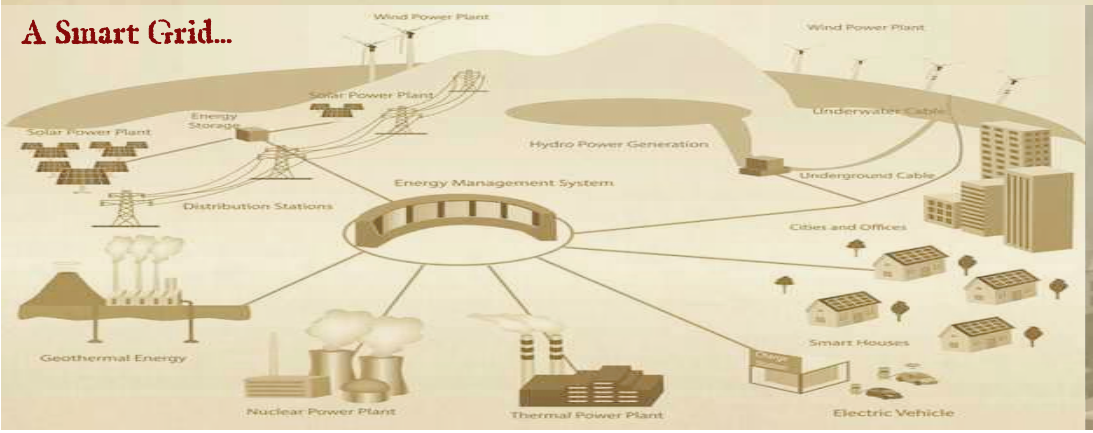
This transformation and the innovative technologies enabling it will require changes in customer behavior, blur the traditional boundaries between producers, distributors and consumers, and make the management of the system more complex but also more flexible and resilient. A combination of distributed electrification technologies will enable fundamental structural change in the areas of electricity generation, supply and distribution. These changes will have to be performed by a large number of market players, from major corporations and grid operators to regional alliances and private micro-grid units. More renewable energy will be produced on a decentralized basis. Digital appliances and services will affect all levels of the electrical system. Smart converters will be added to passive grid components such as switches and transformers. The number of power electronic converters used in the energy supply system will rise steeply. Because individual energy systems for electricity, heating and air-conditioning and mobility are evolving into multimodal systems, the challenge is to enable different energy sources to interact in these systems. As power generation becomes less predictable through the use of renewable sources, new storage solutions are required that will help to ensure supply stability. New storage technologies are needed, just like technologies that quickly charge batteries and mobile battery solutions. Beyond these smaller flexible solutions, the next step is storage systems that are particularly well-suited for storing huge amounts of energy over long periods of time such as molten salt facilities, compressed air and flywheel plants.

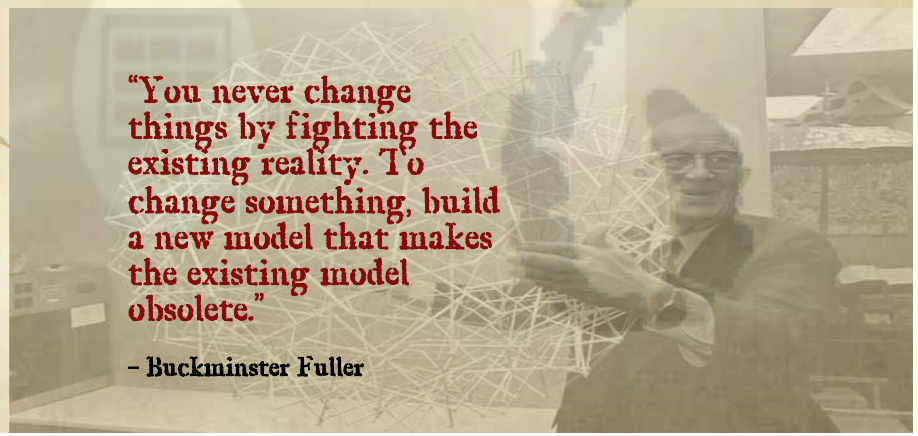
Mirroring nature and going micro...

Micro grids are small, advanced electric grids with features that make them especially adept at managing energy and ensuring its reliable delivery. Self-sufficient, a micro grid serves a discrete geographic footprint, such as a college campus, hospital complex, business center, or neighborhood. Within micro grids are one or more kinds of distributed energy (solar panels, wind turbines, combined heat & power, generators) that produce its power. In addition, many newer micro grids contain energy storage, typically from batteries. Some also now have electric vehicle charging stations. Interconnected to nearby buildings, the micro grid provides electricity and possibly heat and cooling for its customers, delivered via sophisticated software and control systems.

These advanced systems are intelligent. This intelligence emanates from what's known as the micro grid controller, the central brain of the system, which manages the generators, batteries and nearby building energy systems with a high degree of sophistication. The controller orchestrates multiple resources to meet the energy goals established by the micro grid's customers. They may be trying to achieve lowest prices, cleanest energy, greatest electric reliability or some other outcome. The controller achieves these goals by increasing or decreasing use of any of the micro grid's resources – or combinations of those resources – much as a conductor would call upon various musicians to heighten, lower or stop playing their instruments for maximum effect. A software-based system, the controller can manage energy supply in many different ways. But here's one example. An advanced controller can track real-time changes in the power prices on the central grid. (Wholesale electricity prices fluctuate constantly based on electricity supply and demand.) If energy prices are inexpensive at any point, it may choose to buy power from the central grid to serve its customers, rather than use energy from, say, its own solar panels. The micro grid's solar panels will instead charge its battery systems. Later in the day, when grid power becomes expensive, the micro grid may discharge its batteries rather than use grid power. Micro grids may contain other energy resources – combined heat and power, wind power, reciprocating engine generators – that add even greater complexity and nuance to these permutations. Working together via complex algorithms, the micro grid's resources create a whole that is greater than the sum of its parts. They drive system performance to a level of efficiency none could do alone. All of this orchestration is managed in a near instantaneous fashion – autonomously. There is no need for human intervention. In nature a system made of many smaller self-sustained units coming together to form a super-structure are known to offer more resilient and sustainable solutions, a connection of micro grid solutions should be no different.

A Smart Grid...





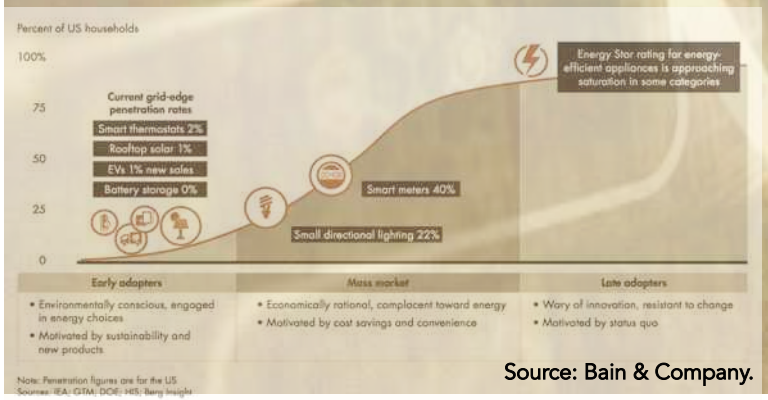
THE BATTERY BATTLE...

The key to unlock the next stage is advances in battery technologies. The battery is a 200-year-old innovation, and the basic technology has not moved on much. All rechargeable batteries work on the same principle of employing two electrodes – the negative anode and the positive cathode – and a so-called electrolyte that separates the two. A battery's performance is measured in energy density. Energy density is a measure of how much energy the battery can hold relative to its weight and size. An electric car or bus needs a battery with a high energy density to maximize the vehicle's range. The related concept of power density refers to how many watts the EV's engine can pull out of the battery. If the power density is high, the EV can accelerate faster and the battery will charge in less time. For battery manufacturers, the challenge is to achieve optimum balance between energy density and power density.

The most common battery in use today is the lithium-ion (Li-ion) battery. With a high energy density and power density, these are used in everything from smart-phones and computers to EVs. Li-ion batteries have been on the market for 25 years, and much of the current research revolves around improving this type of battery. Real significant progress is being made in this space, researchers in Singapore have developed a Li-ion battery that can be charged 20 times faster than current batteries. The battery can be charged to 70% of its capacity in just two minutes. This gives them great prospects for EVs, which today take hours to charge. In addition, the battery lasts 20 times longer than current models. This kind of progress is being made both in terms of technology and materials. In the new battery mentioned above the traditional carbon anode has been replaced with a gel material made of titanium dioxide. This is a material that that's both inexpensive and abundant. Researchers have discovered how to transform titanium dioxide particles into nanotubes that are a thousand times thinner than a hair. This accelerates the chemical process in the battery leading to its outperformance.

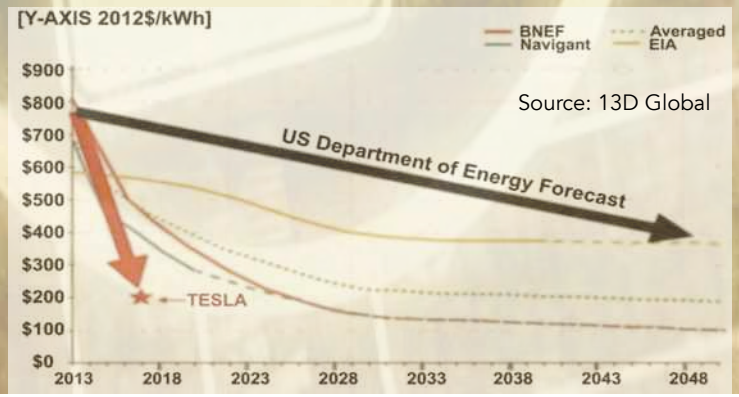
Progress is also being made in what has been described as the 'ultimate battery for EVs' – the lithium-air batteries that produce electricity by means of atmospheric oxygen. The big advantage of these batteries lies with their energy density that is up to 10 times higher than the Li-ion batteries used in EVs today. This means that they produces the same amount of energy per unit weight as gasoline and, therefore, EVs powered in this way would have far greater range on one charge than today. The battery has a weight that's a fifth of today's EV batteries and will allow an EV to run up to 700km on a single charge. The battery also loses less energy when charging and can be recharged more than 2,000 times. There are still issues to be ironed out and it's still at an early stage of development but real progress is right in front of us. Other advanced technologies, such as so-called 'micro li-ion batteries' that's no larger than a grain of sand and can readily be integrated into microchips as well as nuclear batteries that potentially could produce 100 million times more energy than conventional types of batteries and have a lifespan of more than a century, are well advanced. The quest for better and better battery technology is on and real progress is being made that will play a crucial part on our path forward in search of a more efficient energy framework, with far reaching effects on the world's energy mix and beyond.

Most new energy technologies are still in the early adopter phase...



Source: Bain & Company.

Battery price projections...



Source: 13D Global

A LOOK TO THE FUTURE

TODAY:

Your smart-phone must be charged daily. The electric car in the garage can run for a few hundred kilometers on one charge. Solar panels on a house roof provide no energy at night and battery storage systems are expensive and in early-stage development. Most technologies are at early-stage penetration rates.

2035:

Your smart-phone can run for weeks on a single fast charge. EVs can easily handle 1,000 km on one charge, but a charge still takes some hours. Energy from high efficient solar cells can be stored in an integrated battery system and/or form a part of a smart micro grid solution.

2050:

Your smart-phone is powered by your smart textile clothing or directly from integrated micro solar cells. Integrated solar panels supplement super-batteries that only rarely need charging on EVs. Integrated solar panels provide all power for the home, both day and night and smart micro grids drawing on multiple renewable sources power whole cities and industrial complexes.

"The cost of battery storage for stationary applications will fall by up to 66% by 2030 leading to a 17-fold increase in installations of battery storage." – The International Renewable Energy Agency.

A SUMMARY:

Our investment case:

We live in an energy hungry world. Global GDP is set to treble by 2060, with two thirds of that growth coming from emerging markets which display significantly greater energy and carbon intensity per unit of GDP than developed markets. As we have illustrated in this report, each of the renewable sources of energy – Solar, Wind & Water could if technologies are maximized, more than cover all of our needs – now and in the future. Add next generation nuclear and some of the more marginal renewables such as geothermal and we have a glut of solutions being unleashed by innovation.

We have no need to dig stuff up and burn it. The future will likely be won by a combination of these technologies, supplying ever increasing amounts of energy from more and more complex and efficient types of technologies. Such progress driven by both private and public enterprise will need more than just compounded technological advances, financing models and economic market places, systemic innovation including physical and digital infrastructure and public policy will need to be introduced in order to maximize this gigantic opportunity.

As we observed in our '8 Pages About Investing in Innovation' report; "We tend to overestimate what can be achieved in a year or two and underestimate what can be achieved over decades." And in the same report we went on to draw a few key lessons from history that will also be important to heed when looking at this segment, namely the observation by Mr. Jared Diamond:

"My two main conclusions are that technology develops cumulatively, rather than in isolated heroic acts, and that it finds most of its uses after it has been invented rather than being invented to meet a foreseen need. (…) Because technology begets more technology, the importance of an invention's diffusion exceeds the importance of the original invention. Technology's history exemplifies what is termed an autocatalytic process: that is, one that speeds up at a rate that increases with time, because the process catalyzes itself."

Changes in the world's energy mix has been a source of historic wealth creation and destruction, and today investors would be prudent to take note of what is under way.

Innovative companies are set to reap the rewards of harnessing the winds of change in an industry that a recent Citi Bank report forecasts will be the beneficiary of around $200 trillion (both capital expenditure and fuel) over the next quarter century. History shows that innovations in technology can cause dramatic increases in productivity, transforming industries and setting whole societies on new paths to growth. The world is approaching a tipping point in the development of energy technologies that could generate increases in energy productivity on a scale not seen since the industrial revolution. It is difficult if not impossible to talk about energy without mentioning innovation. From the light bulb to unconventional production or clean energy, examples abound.

Just to cite a few figures, unconventional gas now accounts for 40% of US natural gas production and renewable technologies accounted for 42% of total power capacity added worldwide in 2012. Take the solar industry during the last 15 years annual installations of photovoltaic systems in the US has grown from 4 megawatts (MW) in 2000, to over 6,000 MW in 2015. This is a compounded annual growth rate of nearly 70% and a total growth rate of 155,000%. Even during the last year with low oil and gas prices the renewable industry finished another record-breaking year, with more money invested, $333.5 billion, and more capacity added, 121 Giga watts, than ever before according to BNEF data.

Over the last 5 years the US shale revolution has upended oil and gas markets in the US and the world at large. At first it was dismissed as unworkable, then it was minimized as unsustainable. Now, having helped drive a massive drop in the global price of oil, it is hailed as an economic and geopolitical game changer. The electricity sector is quietly undergoing its own transformation, and it is set to yield dramatic economic and social benefits.

Thanks to technological innovation, smart government regulation, Chinese industrialization and creative financial engineering, solar panels are becoming cheaper and more accessible than ever before and the consequences are likely to be profound.

As discussed, batteries too, have the potential to change the world just as much as shale has, should the technology continue to improve. That's because large-scale batteries could unlock the full potential of renewable power, which has been held back by its intermittent nature.

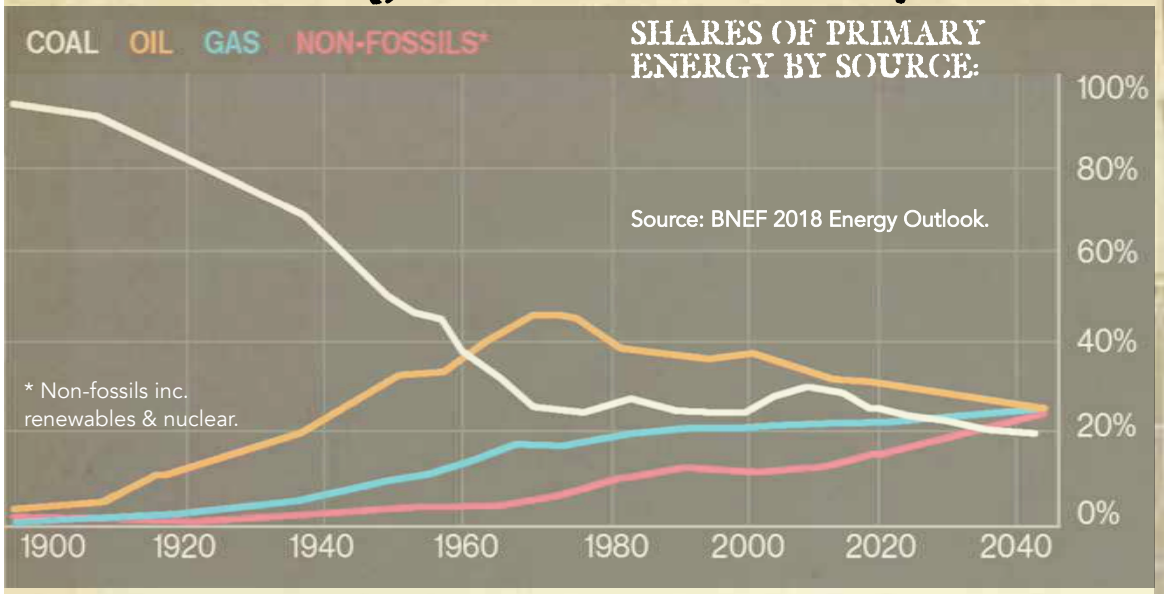
EVs are already evolving into a significant reality that is only set to expand and again the development of viable low-cost, large-scale batteries could be the game changer. As mentioned solar panel prices have already plummeted with wide ranging positive side effects, and batteries look set to follow in the future again with significant knock-on effects across industries.

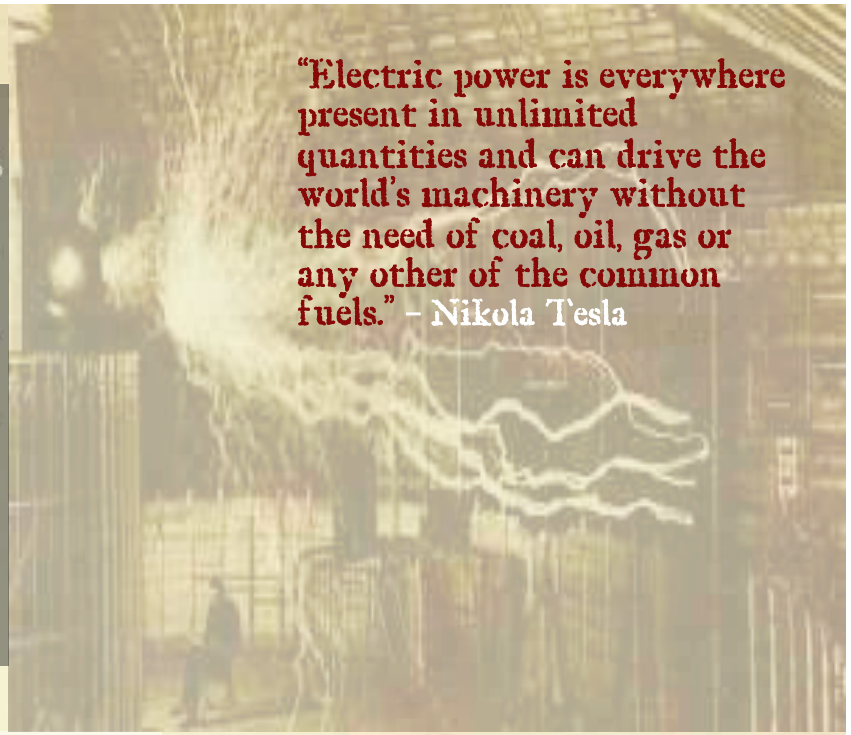
The energy sector offers many opportunities – now and in the future – and in our opinion, as an investor you can't afford not to be on the right side of these changes. The actionable investment universe is wide and deep – from innovative companies across all the segments we have covered, to materials such as graphene, lithium & thorium and the nations that hold them and the companies that mine them, to the utility companies with the foresight to get out in front of these trends, and private ventures that are established to replace the ones who get left behind with their own micro-grids feeding into a larger global network should be great cash yielding assets with underlying real assets such as land and installations. A diversified set of holdings that is right for each investor can be devised in this universe, for now and the future. **Put some power in your portfolio.**

$333.5Bln: Amount invested in global renewable energy projects in 2017.

"Often the greatest opportunities are around the edges of things...When everyone is looking at something in a certain way, looking at it a little differently can be increasingly refreshing and rewarding." – Mr. Klarman

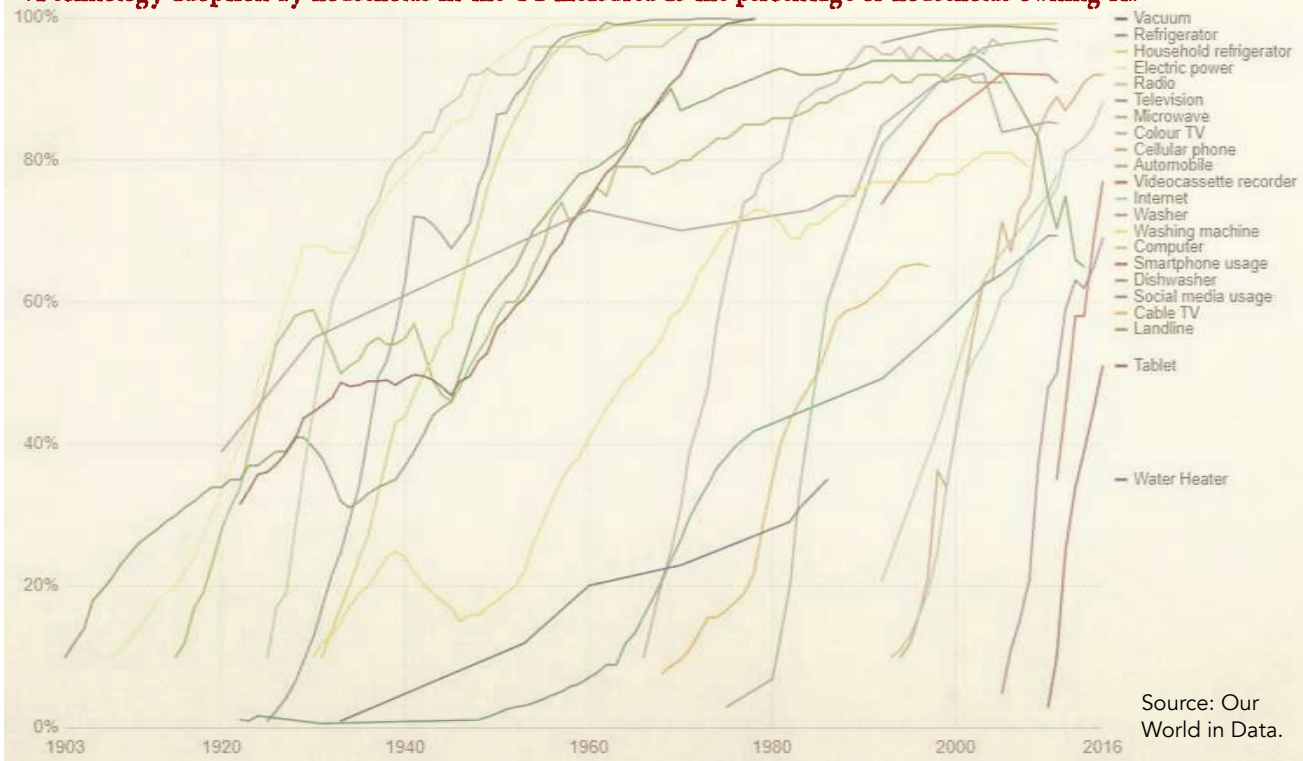
Random thoughts from the journey...





THE POWER OF A TECHNOLOGY WHOSE TIME HAS COME...

(Technology adoption by households in the US measured as the percentage of households owning it.)



When investing in innovation for maximum returns you are investing around things that have not happened yet. Bring your imagination and a large dose of pragmatism and an understanding of the the lessons of history. - From our "8 Pages About Investing in Innovation' report.

"The ability to understand how seemingly disparate developments can create new business models and applications requires a more expansive perspective focused on connecting the dots and exploring new ways to apply knowledge and insights." - Mckinsey & Co.

SOURCES & INSPIRATION...

In the words of Sir Isaac Newton: "If I have seen further it is by standing on the shoulders of Giants." On this page we humbly give thanks to those great individuals, source materials & books that provided us with the insights shared in this report.

The Reports & Articles:

Bain Brief: Harnessing the value of grid edge technologies by Bain & Company.

S&P Global Market Intelligence: How Virtual power plants are allowing US utilities to embrace disruptive technologies by S&P.

The solar highway that can recharge electric cars on the move by Bloomberg.

Future Energy by Bringing Science to life.

Germany back European battery champion to take on Tesla by Bloomberg.

Tumbling costs for wind, solar, batteries are squeezing fossil fuels by BNEF

Ceramic pump that takes the heat promises cheap, efficient grid storage by MIT Technology Review.

Wild is the wind: The resource that could power the world by the Guardian.

Watch & Learn:

Here Evelyn Wang takes a look at the important role that advanced materials plays in the future of energy:

https://www.technologyreview.com/video/609399/from-the-lab-inventive-approaches-to-sustainable-energy/

This is an excellent overview on the technology behind Thorium powered plants by Kirk Sorensen:

https://www.ted.com/talks/kirk_sorensen_thorium_an_alternative_nuclear_fuel

Interesting websites for news on the future of energy:

https://www.greentechmedia.com/#gs.cfFcGLg

http://www.world-nuclear.org/

http://energyfromthorium.com/

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We also provide intra-monthly event driven insights as a part of our constant horizon scanning services.

Our services can also be employed on a retained basis, providing the client direct & always confidential access to our team on an on-going basis allowing us to act as an independent sounding board for our clients ventures.

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