Case Study March 2012

Online Trading Has a New Color

eBay Green Programs and Initiatives

By Anuradha Munshi

Executive Summary

As one of the world's largest online marketplaces eBay is an organization with widespread global reach, industrial knowhow and a very substantial user mind share. With around a hundred million active users today who buy and sell goods online using this trusted brand name, the potential for such a platform to act as a catalyst and drive messages of sustainability and green products within its community is huge.

How does a company like eBay that facilitates online transaction of goods, deploy strategies which help drive green programs? How does it blend these initiatives with its traditional model of online trade in a way that enriches its existing culture and prepares it for the future? This report holistically examines various methodologies that eBay has adopted that lead it on the path of sustainability.

Foremost in its culture is the presence of a self-organized, grassroots and cross-functional group called the eBay Green Team which is responsible for employee engagement and driving various internal and external environment friendly initiatives from eBay. The company has also launched online green programs that encourage reuse and recycling of products by either directly reaching its user base or partnering with other green businesses. The usage of its Paypal service by businesses to transition to paperless transactions is yet another green solution.

On the other end of the spectrum eBay has also been making various green investments in reshaping its infrastructure. This report examines strategies that lead to reducing energy usage in eBay data centers and office campuses. At a corporate level eBay also lends its voice to worldwide initiatives around sustainability. All these efforts come together in defining a green movement at eBay.

Introduction

There are few companies that capture the mindshare of millions of people. In the world of online trading, eBay, one of the world's largest online marketplaces with over 97 million active users who trade online, and with a similar number of users registered on PayPal making financial transactions, is one such company. With widespread global reach, eBay's initiatives and commitments towards promoting sustainability have the potential for a significant impact. eBay contains all ingredients that are vital to making this transformation. From a volunteer grassroots team, to partnerships, programs and infrastructural investments, the company is on the path towards a greener future.

The eBay Green Team

At eBay the campaign of going green is led by the eBay Green Team. Made up of volunteers who are eBay employees and users, the green team's focus is to drive various initiatives that center on the idea of promoting and educating sustainability to both its employees and community members [1].

Coming into being - The movement to go green at eBay started in 2007 with a group of 40 like-minded employees who decided to work together to find ways to make the company greener. At its launch, it was called the Eco Team. The idea caught on rapidly and soon became an official group within the company known as the eBay Green Team. Today the team has grown to 2500 active eBay employees representing 28 countries of the world.

In 2009, the green team publicly extended its membership to eBay users around the world based on an assumption that green initiatives would also matter to a larger community. The result spoke for itself; 40,000 people joint overnight and in 6 weeks, membership grew to 100,000. This program has more than 300,000 members today. The eBay green team is now a large community of volunteers who champion the cause of sustainability within the company.

Initiatives – The Green Team drives concepts unique to eBay such as Green Shopping while helping promote sustainable commerce and environmentally friendly businesses. Some of the local initiatives that the green team has been responsible for at their office include grassroots activities like banning of water bottles on campus, engaging employees in low carbon diet campaigns by collaborating with healthy caterers in their cafeteria, planting community gardens, housing Earth Day, organizing activities like Bike to Work week, organizing events for Electronic Recycling and for brainstorming green ideas from office employees. These efforts aim to generate interest about the environment within the office community.

Along with employee engagement initiatives, the eBay Green team has also been a catalyst for large scale projects like eBay's investment in the construction of its LEED certified green building in San Jose, and the city's largest commercial solar installation, initiatives which reduce carbon emissions by a million pounds per year and save more than $100K. The eBay green team retains its grassroots appeal while formally enjoying support and commitment of the management as it drives various green programs in the organization. The team has a public website where it tracks its ongoing efforts.

eBay Green Programs and Initiatives

The eBay Green Programs

At a corporate level, eBay has launched various programs that are aimed at encouraging sustainable and green products. Through its online marketplace, the company enables product recycling through resale, and keeping items in use and out of landfills. Here are some of the most recent online initiatives from their green-program that promote sustainability:

Instant Sale Initiative

The eBay Instant Sale initiative is an online tool that allows customers to get cash for reselling used or old electronics like smart-phones and other devices, helping prevent these electronic items from entering landfills.

By answering a few questions about their old devices and getting a cash-offer instantaneously, sellers are able to dispose of their old electronic items in a very eco-friendly way – by trade – while eBay through its commercial channels and partners ensures that these goods are traded for reuse and that landfills are avoided.

With this solution launched in 2010, eBay tries to address the problem of redundancy of electronic items in the market today. Their solution helps in keeping e-waste out of landfills and reduces the need for new manufacturing. Even if the item listed for sale has no value, eBay still provides a pre-paid shipping label so that their partner can recycle the product based on the rigorous e-stewards certification. This encourages recycling of products via a channel that most people are accustomed to for trading products. In essence with the Instant Sale Initiative program the company helps recycle products for users and rewards them for it.

In 2011, eBay calculated that through the number of used iPhones alone that were traded in via this program1,040 tons of CO_2 were offset, resulting in energy saved that could power 85 homes per year in the U.S [2]. The challenge for the Instant Sale initiative is to quickly become a role model so that items other than electronic goods can enter eBay's recycle-and-get-paid methodology. With over 4.3 million offers having been made to date on this initiative, the program today has been expanded to address local markets outside the U.S, in Germany and Canada.

The eBay Box

Packaging and shipping are essential parts of online transactions, and when eBay offers Green packaging with its eBay box, it opens doors to new opportunities for a greener environment. Announced in September 2010, the eBay Box program brought 10,000 recyclable and durable boxes to buyers and sellers across the country.

These packaging boxes enable an environment friendly option for packaging. According to the company, if every such box gets re-used at least 5 times, that would be the equivalent of protecting 4000 trees, saving 2.4 million gallons of water, and conserving enough energy to power 49 homes a year [3]. eBay has also worked with the United States Postal Service to extend their green package solution to a broader community. In 2007 eBay introduced an environment-friendly Priority Mail packaging in collaboration with USPS. These "cradle-to-cradle" certified packages are available for free today to users at eBay.com in its USPS shipping hub.

The eBay Dwell on Design program

eBay also promotes the green movement by regularly showcasing green home products from its top green sellers. This solution encourages brand recognition of individual green sellers.

An example is the company's promotion of the "Dwell on Design" green designer home that it regularly sponsors in Los Angeles. Presented by EcoFabulous and Electrolux, the green home showcases top luxurious green interior design and lifestyle choices, and features green products that are also available on eBay.

The items that are showcased in these walk-through green designer homes include energy efficient appliances, water saving faucets, rapidly renewable cork flooring and various other renewable materials. This promotes and incentivizes both green sellers and buyers. Through its "eBay Giving Works" program, the company also helps in auctioning the designer green home to the community.

Recycle Bank

Recycle Bank is a green loyalty program that eBay has teamed up with, to reward its consumers for recycling and reusing existing products. This program grants points to eBay users based on how much they are able to recycle. These points can then be redeemed at various stores and outlets. Another option is for people to donate these points to the Recycle Bank Green Schools Program, which offers grants for environmental education locally. Today this program serves over a million eBay customers in the U.S., continues to grow internationally, and has received prestigious awards from the U.N

Promoting Green Businesses

As one of the world's largest online marketplaces with a global supply chain distribution and industry know-how, eBay as a platform brings an opportunity to other green businesses to collaborate and expand on their sustainable ideas. This section highlights a few real life examples of eBay collaborations with other green businesses that promote sustainable ideas in the market place.

Knetgolf: Collaborating with eBay

eBay has helped many people rapidly expand and flourish their green businesses. For example, Canadian eBay seller Shaun Shienfield converted a business opportunity of collecting and selling lost or used golf balls into knetgolf - a $20 million business today – by being able to successfully sell online via eBay [4] and growing his business.

This is a green business model since by cutting down the need for new golf balls, knetgolf also cuts down large amounts pollution, oil-derived plastics and adhesives that would have resulted in manufacturing new golf balls.

eBay Green Programs and Initiatives

Knetgolf this year will sell 10 million of these “recycled” balls on eBay alone. Besides hosting knetgolf on its marketplace, eBay also recognizes and promotes such green initiatives; in 2009 Knetgolf received the 2009 Entrepreneur of the year award from eBay Canada [5]

Patagonia: Common Threads Initiative

eBay has partnered with Patagonia, the maker of outdoor apparel in promoting the durability and reuse of clothes. The Common Thread Initiative store brings Patagonia’s pre owned clothing and gear to the eBay marketplace. Users can buy pre-owned Patagonia clothes and gear, while sellers can have their used Patagonia clothing section listed on Patagonia.com if they take the Common Thread Pledge online.

The Patagonia Common Threads Initiative is eBay’s first ever branded storefront that features pre-owned listings from sellers. eBay further incentivized this effort by offering gift certificates for reselling Patagonia clothing online. This type of a business model with Patagonia is another example of how eBay’s marketplace can enable trade of sustainable articles and how sellers of green products can collaborate with eBay’s marketplace and with a large user base to promote green businesses.

WorldOfGood: Promoting a Social and Environmental Marketplace

In 2005 eBay teamed up with WorldOfGood.com to create one of the world’s largest marketplaces for ethically sourced eco-friendly products.

As a channel for local artisans and entrepreneurs from all over the world to sell their products online, WorldOfGood.com realized it’s potential by joining hands with eBay. This brought one of the largest online marketplaces with global distribution, supply-chain know-how and industry credibility to a business that promotes local artisans who create ethical and environment friendly products.

Today eBay’s WorldOfGood.com website provides a trusted platform where individuals as part of a global community can create positive change through commerce. In 2010, eBay acquired WorldOfGoods.com [6], and in 2011, eBay’s WorldOfGood.com was the winner of the prestigious “Nobel of Sustainability” award promoted by the U.K. based charity firm Katerva [7]. eBay was selected from a list of 150 nominees worldwide each of whom had been evaluated based on feasibility, marketability, scalability, originality and impact.

Online Green Shopping

eBay provides its users a webpage through which they can specifically purchase green products. This page is dedicated to green buying and selling, or “green shopping”. Products like energy efficient light bulbs, EnergyStar™ appliances, and various recycled goods can be located at this URL. Green shopping makes it easy for both buyers to look for the latest green products and for sellers to sell and ship their green products through eBay.

Going Paperless with PayPal

A unique way in which eBay's PayPal service helps the environment is when third party programs use it to reduce paper statements in their business models.

As an example, Parago, a provider of innovative reward programs for promoting brand loyalty, announced in 2010 that it would use PayPal for offering rebate payouts and awards to loyal customers [8]. This collaboration with eBay helped Parago replace its paper based model with PayPal's paperless transaction model that had a pre-established mind share within its user base.

The PayPal service today reaches more than 100 million active accounts and enables paperless financial transactions leading to a large number of trees that are saved as a result. eBay also extends their paperless solution with PayPal X, an open platform that enables green sellers and developers to build payment solutions on multiple platforms and devices while reaping the benefits of a paperless transaction system.

Greening Buildings at eBay

Another way by which eBay promotes sustainable solutions is by investing in its own infrastructure to implement energy efficient renewable solutions. Over the years eBay has been redesigning its office campuses as well as its data centers in order to use renewable energy and to implement industry best practices to reduce Green House Gas (GHG) emissions. The company has been judiciously measuring all Scope 1 and Scope 2 GHG emissions of their inventory, and a portion of Scope 3 emissions have also been evaluated. eBay has set a target of reducing greenhouse gas emission levels by 15 percent in 2012 over 2008 emission levels. This section highlights some real life examples of infrastructural initiatives by eBay that are aimed at reducing carbon footprint and bringing in energy efficient solutions.

Greening Data Centers

For a company that thrives on online transactions, backend infrastructure like data centers plays a key operational role. Data centers can cost a lot to any company in the amount of electricity that gets consumed, especially for a company like eBay whose operations are very data intensive. To address this problem, the company's data centers are often optimized for using alternate renewable energy sources like solar, while newer data centers are built with green-innovation in mind, reducing the carbon footprint.

A good example is eBay's data center in Denver, where it has invested about 100kW of renewable solar energy that it expects to payback within 3.5 years, thanks to local tax rebates and incentives [9]. The solar power derived from this data center is used to run non-critical loads like supplying office space power for desktops used by its 35 employees.

The solar array which takes approximately 18,000 square feet of the roof can produce up to 500 kWh a month in peak summer months. The excess energy produced is sent back to the electric grid and eBay gets credit from the local power company for that power. Even with 2 inches of snow-cover the solar array is able to produce around 196 kWh per month during winter [10].

A more intrinsic example is the LEED Gold Certified data center called **Topaz** that eBay developed in Utah where industry best practices for power management have been deployed [11]. In May 2010, eBay opened this state of the art data center that utilizes industry leading practices like natural cooling and real time energy usage adaption, techniques that help lower energy consumption from the grid. The center also showcases innovativeness in the data center's green design and operation. The data center's power and infrastructure management earned it the Environment Project of the Year Green IT award by Green IT magazine. The award winning features include the following among others:

- **Hot Aisle Containment –** Separating the hot air that comes out from the servers from the cold air that goes into them was a key feature for increasing energy efficiency that was deployed by eBay in Topaz. The detail to design was inherent during the building of the data center itself; this design was experimented with full scale mockups among other designs before choosing the optimal architecture for placing their servers.

- **400V Power Distribution –** Conversion losses that are typical when converting electricity from the grid were reduced by powering up the servers to 400V instead of the typical 208V. This design decision allowed eBay to save on 2-3% of typical conversion losses, and added up to their savings.

- **Server Power Instrumentation –** For evaluating the cost of the lifetime of its equipment including servers, eBay calculates the exact energy used by the equipment over its lifetime, including its one time purchase cost. This methodology helps in understanding the true cost of equipment for accounting purposes.

- **Granular Temperature Instrumentation –** Cabinet level temperature measurements were carried out and used in Topaz for precisely engineering the hot and cold air separation and temperatures. This technique helped eBay avoid unnecessary cost and energy of buffering the whole data center.

- **Overhead power distribution busway -** Putting the numerous power supply cables over the server cabinets helps not only in removing complicated mazes of cables on the floor or over the sides, but also is a very efficient way of allowing the flow of cool air throughout the data center. This technique was adopted in the Topaz data center.

Project Mercury–eBay had been using leased facilities in many places for its data centers which inhibited its ability to optimize energy savings. The company also wanted to consolidate many of its data centers in order to create a state of the art data center for managing its next generation of online data storage and searching capabilities.

The newest data center from eBay in Phoenix Arizona, dubbed Project Mercury, was created to address both these problems.

The project consolidates 11 data centers into 3 locations, moving out of leased facilities into ones where eBay can own and control the energy usage. Developed with guidance from The Green Grid [12], eBay's Phoenix data center implements many of the current and future best practices proposed by the Green Grid's Data Center Maturity Model (DCMM) released in February 2011 [13]. Here are some key features used in development of this data center:

- **Efficient Cooling Designs:** By efficiently designing the center, free year-round cooling is provided for the entire computing environment even at desert temperatures that reach 119F.The water-side economizer cooling works 100% of the time with chillers utilized only for backup, despite desert temperatures.

- **Modular architecture:** The data center is built on a modular and scalable design that can handle five generations of future technologies. Another benefit of a modular design is that multiple RFPs could be issued to different vendors which increased competition for data center efficiency.

- **Server Optimizations:** Individual server models are optimized for low power consumption and software is deployed to dynamically change a server's CPU clock frequency to match workload demands. Other server optimizations include dense rack deployments as well as optimizations in the server-rollout process for both rack-at-a-time and container-at-a-time systems to support rapid scalability.

- **Choice and deployment of metrics:** Green Grid's PUE (Power Usage Effectiveness) metric was used as a key design element during the design phase of the data center instead of only using it as a metric to measure efficiency after the center was built. Another metric used was the Total Cost of Ownership (TCO) metric which calculates the total energy usage by eBay per equipment's lifespan [14].

The stated goal of project Phoenix was to achieve a PUE of 1.2. eBay reported that the average PUE on the site was 1.35 during one week in January 2012, with a 1.26 at its best. Partial PUEs of 1.04 also have been reported by the company. With data centers accounting for nearly 50% of eBay's global power usage, measures like these are critical to managing its greenhouse gas emissions footprint and protecting itself against rising costs of conventional energy sources. These infrastructural investments around sustainability are designed to benefit eBay in the long run.

Greening its Campus

The eBay headquarters at San Jose is served by Fuel Cell technology from Bloom Energy - a strategy that has yielded savings in electricity consumption since these were installed. More than $100,000 has been saved since installation of 5 fuel cell boxes in Feb 2010, as of August 2011 [15]. These Fuel Cell Boxes take 15 percent of the campus energy needs off the grid completely.

eBay has also invested in a 650 kW solar PV array at its San Jose campus. 3,248 panels, equivalent to the size of a football field, cover eBay's roof space [16]. These panels provide renewable solar energy and additionally remove about 18 percent of the campus' energy completely off the grid.

This solar system, a partnership of eBay and SolarCity, is one of the largest installations in San Jose and will offset 37 million pounds of CO2 over the next 3 decades. With an estimated annual renewable energy production of 888,061 kWh the installation has helped save the company around $100,000 in the first year of installation in 2008. The San Jose campus building is **LEED Gold Standard** certified and it was the first building in the city of San Jose to receive the LEED Gold standard certification from the US Green Building Council.

Advocating Green Policies

Lending its voice to various green policies and initiatives around the world, eBay also participates in worldwide environment policy and legislature. In 2007 it signed on the Bali Communiqué on Climate Change, followed by the 2008 Ponzan Communiqué on Climate Change, and the 2009 Copenhagen Communiqué on Climate Change. All such initiatives call upon the United Nations to develop a comprehensive, legally binding framework that addresses climate change. eBay also participates in relevant public policy discussions in BICEP (Business for Innovative Climate and Energy Policy) which is a coalition of U.S. consumer brands advocating for aggressive climate policies.

It also collaborates regularly with government entities, non-profit agencies and peer companies through organizations such as Sustainable Silicon Valley, Business for Social Responsibility, CERES, and the World Resources Institute Green Power Market Development Group.

The Green Road Ahead

All of these real world initiatives show how eBay, a leading facilitator of online trade and reuse of products, can reshape a successful online marketplace to catalyze adoption of green practices among its users, partners, as well for itself as a company. Driven intrinsically through its eBay green team, the company seeks innovative solutions to promote a green products marketplace through its online green-initiatives, collaborations with other sustainable businesses and solutions, and by investing in its infrastructure to enable green solutions.

While going green certainly saves eBay money, it also provides a path to contribute towards building a more resilient future by promoting green practices and awareness among its user base. With eBay progressing on this path, the color of online trading promises to change to a better shade of green for tomorrow.

References*

***Please refer online at eBay.com for the latest information on the eBay green programs as the links and information may be subject to change in the future.**

1. The eBay Green Team
2. The fight against e-waste
3. eBay debuts the eBay box
4. The eBay Knetgolf store
5. eBay Canada recognizes top online entrepreneurs
6. eBay acquires WorldOfGood
7. eBay WorldOfGood.com wins prestigious Nobel of Sustainability award
8. Parago leverages Paypal to extend greener customer promotions
9. eBay's solar installation in Denver data center
10. How investing in Solar helps eBay
11. eBay data centers employ industry best practices
12. How eBay built its new energy efficient data center
13. Green Grid DCMM Model
14. Green Grid White Paper on eBay Data Center
15. eBay uses renewable fuel cell energy at campus
16. Solar City white paper on eBay San Jose campus project

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Case Study

NetApp – Greening its Data Centers

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Background

NetApp (formerly Network Appliance Inc.) creates storage and data management solutions for its clients.

It focuses on providing cloud-based storage and solutions (also known as data storage and data management solutions) to various IT vendors or to companies that have business needs for storing large amounts of data.

Headquartered in Sunnyvale, California, NetApp was founded in 1992, received funding in 1994 and went IPO in 1995. It thrived in the internet bubble years (1990-2000) and saw a huge growth in its revenue. After the internet bubble burst, revenues declined but have picked up since 2002 and have been steadily climbing since then, surpassing previous levels in 2009.

In 2011 Fortune magazine listed NetApp as the 5th best company to work for - an award category that the company has been repeatedly earning over the years.

INTRODUCTION

As an industry leader in data storage solutions, NetApp provides both hardware and software solutions for data centers for its clients. In order to better optimize its value chain of products and services, it also conducts extensive testing to maintain and enhance product quality. Several years ago, it became clear to NetApp that its existing engineering and testing labs were reaching maximum capacities. Having had experience in building, customizing and optimizing data centers for clients, the company decided to develop a data center of its own – one that was built on design innovations from its existing labs and that could focus on maximizing energy efficiency.

In 2006 NetApp initiated a project for creating its first data center that was built around the principles of designing for energy efficiency. The result was its Research Triangle Park (RTP) data center in North Carolina, which became the first U.S. data center to achieve Energy Star Certification from the U.S. Environmental Protection Agency (EPA). The RTP center earned 99 out of 100 points from EPA's rating, where the passing standard was 75. NetApp was one of the first companies to describe its best practices for achieving energy efficiency in its data centers which helped the EPA standardize its data.

Initially designed to just meet their engineering needs, these data centers from NetApp gradually started deploying better and more optimizations for achieving energy efficiency, and are now good examples of green building design that showcase how to achieve low power usage effectiveness. For example, the RTP data center developed by NetApp, also called the Global Dynamic Lab (GDL) data center, achieves a PUE (Power Usage Effectiveness) of 1.2 which is an EPA industry standard. Similarly the Sunnyvale data center was designed to minimize power usage and energy required for cooling, and targets a PUE of less than 1.3.

SUSTAINABLE SILICON VALLEY

Measuring Data Center Efficiency with PUE

Power Usage Effectiveness or PUE, developed by the Green Grid, is the accepted metric to quantify the energy efficiency of a data center.

PUE measures the ratio of the total amount of power used by a data center (Total Facility Power) to the power delivered to a computing element, like a server.

The emphasis is on finding how much power is used by the computing equipment, in contrast to cooling and other overhead, and optimizing this value.

PUE = Total Facility Power / IT Equipment Power.

The ideal PUE is 1.0. DCIE, the reciprocal of PUE, is also a metric that is advocated for measuring efficiency; however this metric is not the standard today.

PUE	vs. Level of Efficiency
3.0	Very inefficient
2.5	Inefficient
2.0	Average
1.5	Efficient
1.2	**Very Efficient**

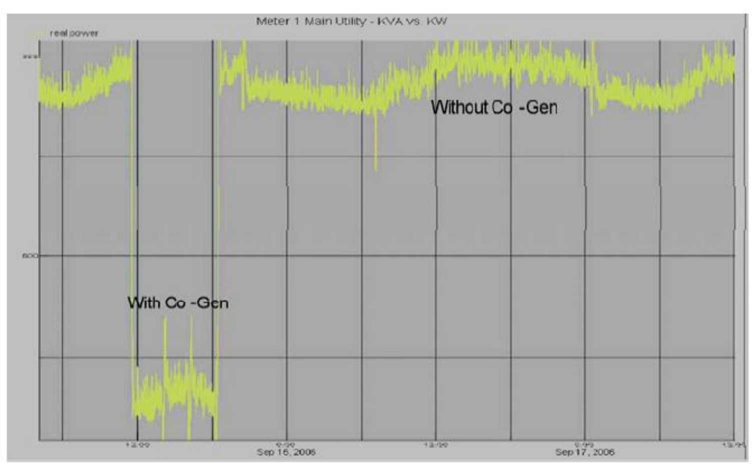
NetApp Data Centers fall under the very efficient category

GREENING ITS DATA CENTERS

How does NetApp achieve high energy efficiencies and low PUEs in their data centers? Some of the best practices and design principles employed at NetApp's data centers that help improve their power efficiencies are summarized below.

Measure to Control – As the first step to optimize energy flow, energy consumption must be quantified and analyzed. NetApp constantly measures power consumption for IT systems, UPS, chillers, and lighting in its data centers. Based on its analysis, energy efficient alternatives are employed wherever it makes sense.

For IT systems, simulations of typical workloads are used to measure and identify power requirements for servers and storage in the labs. Power to the racks is measured continuously to identify problems and to balance loads. Temperature sensors are installed and monitored around each rack to identify hot spots. Alternatives are used where they help improve efficiency – A Flywheel UPS is used instead of a battery-based system to eliminate the AC/DC/AC conversion losses that typically occur in a data center. Occupancy sensors are used for lighting to help conserve energy by shutting off the lighting automatically when it is not required, while an Energy Management System (EMS) measures chiller flow, temperatures and tonnage and provides detailed analytics.



Measuring power consumption

Shown above is a NetApp software measurement tool for analyzing power consumption changes as a function of co-generation.

Benefitting from Virtualization Model

AISO, a website hosting provider based in Southern California in 2006 moved from using physical servers with direct attached storage to using virtual servers and virtualized NetApp storage.

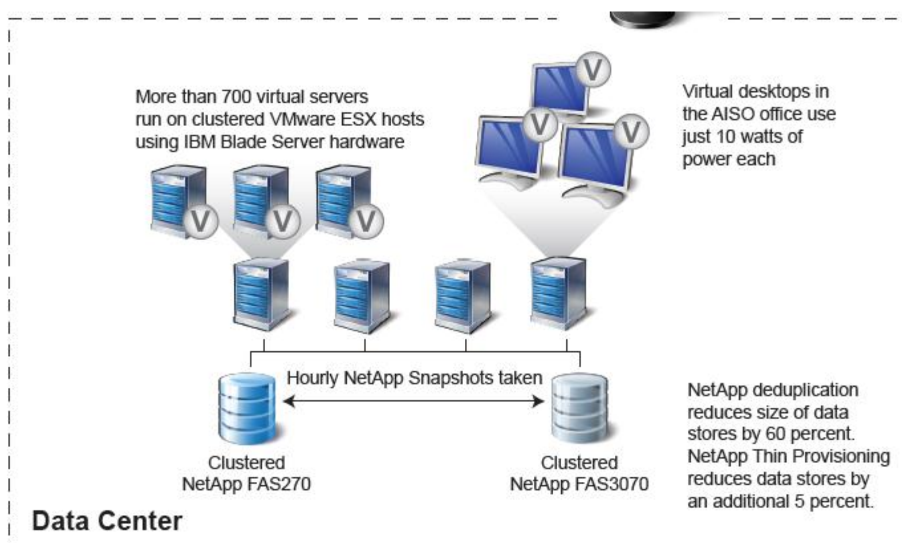
Using NetApp's FAS3070 storage, along with NetApp's proprietary technologies like FlexClone software, FlexVol and SnapRestore proved beneficial for the provider; a Total Operational and Economic Impact (TOEI) analysis by the Alchemy solutions group identified approximately $1.8 million dollars of savings that AISO realized from 2006 to 2010 - by employing server virtualization energy efficient measures from NetApp.

Virtualization helps not only NetApp in creating energy efficient data centers, but also helps its clients when they reap the benefits of a highly efficient infrastructure in lowering their costs.

Virtualizing and Consolidating IT systems – Virtualization is the ability to run multiple machines, services or storage from a single physical resource. Server virtualization, a technology where multiple virtual servers can be hosted on fewer physical servers, provides savings in space, power and cooling for a data center. Similarly storage virtualization in a data center can help create fewer and larger storage systems – again resulting in less power, storage and cooling. By implementing both storage and server virtualization, NetApp has moved towards more energy efficient storage systems.

At least 50 older storage systems have been replaced with 10 systems running the latest storage software based on their Data OnTap operating system. Other tangible benefits include reducing their storage rack footprint from 25 to 6 racks, lowering power requirements from 329kW to 69kW, reducing the air conditioning capacity requirements by 94 tons, and cutting down the electricity costs required to power these systems, as per data available from the company.

The generalized figure below shows how NetApp's clients are able to use NetApp virtualization technologies and achieve power savings as a result.



Managing Data Efficiently– Continuous analysis has often led to higher energy efficiency improvements for NetApp. While implementing its storage model, NetApp analyzed its existing business data and found that nearly 50% of data was redundant or duplicated and could be eliminated. It became apparent that reducing data duplication and eliminating redundant storage would help reduce power requirements, as the physical size of volumes to be backed up would go down. Using proprietary technologies developed in-house, like **Snapshot**, **Flexclone**, **data-deduplication**, **FlexVol** and **RaidDP**, NetApp today addresses and reduces inefficiency in data storage. By reducing its data footprint for backup, power needs also go down.

Eliminating Overcooling of Systems - Most data centers typically overcool their equipment based on manufacturer's recommendations (which are based on running peak loads). NetApp on the other hand first tests the equipment in its lab environments before deploying it in the data center. Its engineers have discovered that cooling requirements or power load estimates for them are typically 30% to 40% lower than manufacturer estimates. This brings down the cooling requirements and saves power. Another optimization to prevent overcooling is the usage of variable frequency drives (VFD) in their air handlers; instead of running fans at 100% speed, sensors constantly monitor temperatures and fan speeds are automatically adjusted. The energy saved is substantial– a 50% reduction of fan speed yields an 87% power consumption reduction.

Creating efficiency via synergy

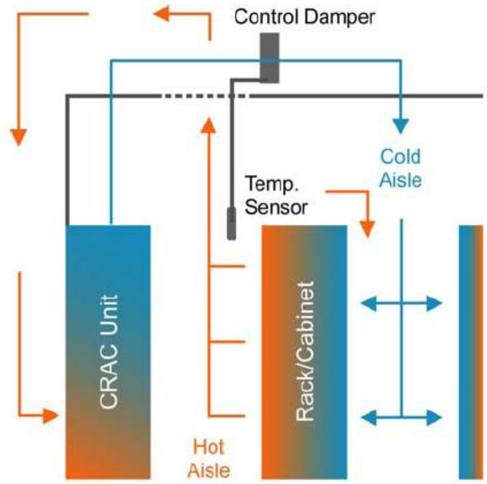
A unique characteristic in NetApp is the synergy between different departments (for example - IT, Facilities) and teams when it comes to implementing features that improve energy efficiency or expand the company's sustainability program.

According to **Peter Perrault**, NetApp's guru for energy efficiency, departments are aware of each other's needs when it comes to improving efficiency, and this informal outlook and approach goes a long way in getting budgets approved and decisions taken for projects that help improve energy efficiency as a whole for NetApp.

The company also has a unique employee program called **VTO,** where employees are encouraged to take 40 hours of paid time for volunteering for anything they consider worthwhile.

Working with Physics in Data Center Layout – Using the principle that hot air rises while cool air sinks, NetApp goes against the traditional practice of using raised floors for providing airflow from below. Instead, cool air is dropped down to the racks, while hot air that rises (for example server exhaust) is vented outside. Also deployed is the "hot aisle/cold aisle" arrangement, where rack equipment are placed face to face or back to back, in order to best improve efficiency. This design is now a standard recommendation for data centers looking to optimize energy efficiency for air flows.

Continuously improving heat containment – NetApp believes that heat containment as a process needs to be continuously improvised in data centers. In its Sunnyvale data center, apart from drawing the hot air up from the racks, hot air itself is isolated from cold racks by using low-cost techniques like vinyl curtains at the ends of hot aisles and around the cooling outtake system above the racks. In its RTP labs in North Carolina, various other measures are employed that yield PUEs from 1.41 to 1.20;these techniques include using overhead Variable Air Volume (VAV) dampers, implementing overhead high density cooling, and deploying pressurized cold rooms, all of which further help reduce the PUE.



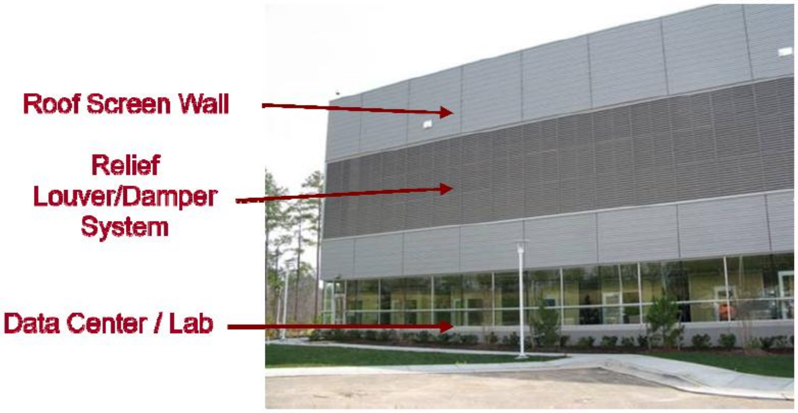
Using VAV for power savings

The variable air volume (VAV) principle that uses a variable frequency drive (VFD) and results in high power savings by lowering the fan speeds, is deployed directly above the hot-cold aisle system at NetApp's RTP data center. This technique helps achieve a PUE of 1.41.

Pressurized cold room tunnel

Another technique deployed at the RTP center is to use pressurized cold rooms instead of cold aisles by enclosing doors at both ends. This technique greatly reduces hot and cold air mixing and results in lower fan speeds which also reduces power consumption, eliminates hot spots and maximizes cooling capacity. This setting yields a PUE of 1.37 and also helps reduce noise levels as the fan speeds are lower.

Maximizing "free cooling" – NetApp's Sunnyvale data center was designed ground up to use outside air for cooling - the sides of the buildings contain dampers that open up when outside temperature is lower than the established temperature set point and allow outside air to flow through the cooling system. When the outside temperature rises, the dampers close and internal chillers take over. This technique alone saves NetApp $1.5 million in energy costs every year.



Raising the bar for free cooling

The environmental engineers at NetApp carefully keep raising the bar for the temperature set point and balancing any side-effects. For example, they expect to raise the set-point to 75F, which could increase the free cooling hours to 85% a year and allow usage of outside air for cooling almost 97% of the time

Gaining with the Utilities

Energy efficiency optimizations yield tangible benefits for NetApp in more ways than one.

In 2008, Pacific Gas and Electric Company (PG&E) presented NetApp with a rebate of $1.4 million for the energy efficient design of its Sunnyvale Data Center and for measures implemented to more efficiently provide power and decrease the energy needed for cooling.

Upgrades included the flywheel UPS, energy efficient transformers, outside air economizers, and a variable primary chiller plant.

With a resulting PUE of less than 1.3 in the Sunnyvale data center, PG&E estimated that NetApp would save more than 11,100,000 kWh each year, resulting in annual reduction of CO_2 emissions by 3391 tons, and an annual savings of more than $1,178,000.

NetApp's rebate is the largest new construction incentive that PG&E has ever awarded.

Minimizing electrical conversion losses – Using the Kinetic flywheel UPS that stores energy as motion NetApp is able to further minimize electrical conversion losses. Flywheels store energy that can be used to instantaneously produce 15 to 20 seconds of energy – which is just enough time to carry out switching operations. This technique, employed at its Sunnyvale data center helps minimize electrical conversion losses.

Using heat that could otherwise be wasted – NetApp uses cogeneration (the process of utilizing waste heat instead of rejecting it) in its Sunnyvale and RTP Data Centers. In the Sunnyvale center the process starts with the heat produced by the natural gas powered generators that are employed. The heat is used to power an adsorption chiller that chills the water in the cooling system. This heat-reuse system used by NetApp has an efficiency rating of 75% to 85%. Cogeneration saves NetApp around $300,000 annually. Cogeneration is also used in its RTP data center where similar benefits are realized.

Constantly monitoring and tuning – NetApp believes that achieving highest energy efficiency levels requires constant testing and tuning of the environment at the rack level. For example, it believes the hot spots or areas that tend to get hot faster should be identified and optimized for efficiency instead of traditional approaches of using fans for these areas. Continuous monitoring is deployed throughout the data center and measurements are constantly taken **-** Multiple temperature sensors are deployed at the mid-level that register an average differential of 10 to 12 degrees, and state of the art Energy Management Systems are deployed that can help continuously monitor the efficiency in the data center.

NETAPP'S GLOBAL DYANAMIC LAB (GDL)

NetApp's Global Dynamic Lab (GDL) data center at RTP (Research Triangle Park) in North Carolina is a fine example of a data center where NetApp designed and implemented everything correctly from ground-up, based on its prior knowledge and experience. The GDL achieves a PUE of the near ideal value of 1.2. Using principles of cooling with ambient air, an innovative building design, and careful project planning in the GDL, NetApp managed to reduce construction costs of the data center by more than 2/3, and annual operating costs by approximately 60% while delivering 7 times more power and cooling to meet the requirements created by the modern highly dense packed equipment racks.

The GDL runs at an average temperature of 74F and employs a green design that saves more than 95,000 tons of CO2 emissions annually.

The costs savings and improvements to NetApp for the GDL essentially come from architectural and structural features that have been employed, from the air handling and water chilling energy efficient designs and from various electrical and lighting optimizations as have been described previously.

Architecturally, the GDL uses a vertically stacked or build-up design rather than a flat, sprawling typical data center design. This reduces the overall footprint of the building. The high rack density that is achieved further reduces the size of the building. An overhead power system distribution and cable plant is deployed that is designed for efficiently managing power delivery to each rack while also eliminating the need for emergency power off (EPO) control devices.

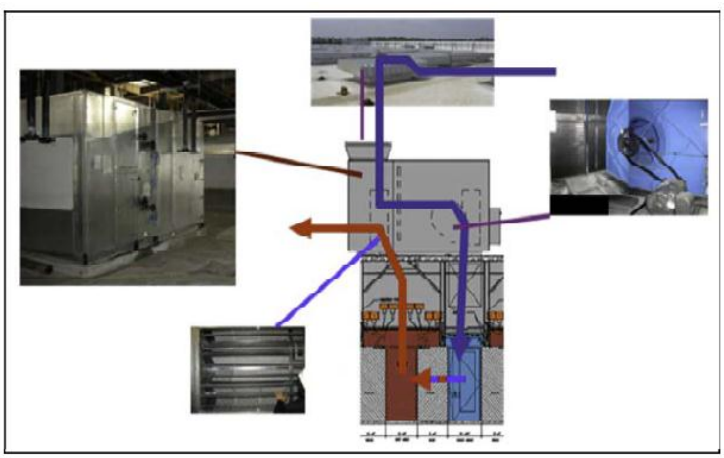
From the perspective of air handling, several of the features and optimizations described previously in best-practices are employed. For example air handlers are placed directly above the racks, the principle of free cooling is employed, and the temperature set-point is raised to around 75F to 80F. Fans and pumps in typical data centers usually overproduce by 30% which leads to energy waste. This is avoided in GDL, and pressure-controlled cooling is deployed to minimize waste.

Setting the PUE Bar

The GDL continuously undergoes optimizations at NetApp. While it was certified as an Energy Star building by EPA in 2009, the optimizations do not stop here.

Peter Perrault from NetApp says that the GDL today achieves a PUE of **1.13**

This raises the bar for what customers and data center manufactures should aim for when optimizing for energy and demonstrates NetApp's commitment towards achieving energy efficiency for its data centers.



GDL's Air Handling System

The Air Handling system at GDL is shown operating in free cooling mode. The air flow is optimized for efficiency when the air handlers are placed directly above the racks. The system also prevents overproduction of fans and pumps, eliminating energy waste.

GDL's water chilling plant also makes use of various energy efficiency optimizations. A prolonged used of ambient air helps reduce amount of time to run chilling plants each year. This means that the chilled water system does not have to be working most of the time. Another advantage is that chilled water supply temperatures get elevated, resulting in about 20% efficiency savings. Finally, the primary chilled water supply volume is variable, preventing starving of water chillers. Reclamation of waste heat is also used during winter months to warm ancillary buildings.

The GDL water chilling plant is shown below

These design practices centered on energy efficiency in the GDL have proven to be good investment returns for NetApp as they help save on annual energy costs, showcase and exemplify sustainable and energy-efficient building design and lend credible brand image to the company in its efforts to innovate and be the market leader.

CONCLUSION

By deploying many of its innovative design practices towards its data centers, NetApp has demonstrated that a properly planned, detailed and well thought of design approach can go a long way in improving energy efficiency in a data center, while meeting near ideal PUE targets. Constant analysis, testing and monitoring of its data can continue to provide feedback for further innovation and help sustain NetApp's growth for the future.

REFERENCES

White papers and business data research:

1. "Breaking down the glass house: NetApp Global Dynamic Lab Delivers High Power Density, Greater Efficiency, and Lower Capital and Operating Costs" – White paper by David Robbins, NetApp, and Mark Skiff, NetApp, May 2010 | WP-7099
2. "10 Techniques NetApp uses for improving data center power efficiency" – NetApp Vision Paper, Feb 2009 | WP-7030-0209
3. "Reducing data center power consumption through efficient storage" – Larry Freeman, NetApp, Inc. July 2009 | WP-7010-0709
4. "Saving energy through storage and server virtualization" –Business Value Analysis Study – undertaking by NetApp, Aiso.Net and the Alchemy Solutions Group.

Online articles:

5. http://www.netapp.com/us/company/news/news-rel-20100714.html
6. http://www.ctoedge.com/content/netapp-wins-epa-data-center-certification
7. http://www.netapp.com/us/library/customer-stories.html
8. http://money.cnn.com/magazines/fortune/bestcompanies/2011/snapshots/5.html
9. http://www.netapp.com/us/company/news/news-rel-20081208.html

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SUSTAINABLE SILICON VALLEY

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Sustainable Silicon Valley is a consortium of over 120 business, government, academic and non-profit institutions working together to build a sustainable economy, a healthy environment and an engaged community. Partners are innovators from all sectors who are creating a nationally recognized model for regional collaboration on sustainability and accomplishing breakthrough results for environmental, economic and social resilience.

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Mixed-Use Energy Tools – Renewables

Name	Vendor	Description	Strengths	Weaknesses	Price[1]	Targeted Audience
Alternative Energy Product Suite (AEPS) System Planning	Alternative Software Concepts, LLC	For the design, modeling, and simulation of electrical power systems with focus on renewables (solar, wind, and hydro). Modeled system can be optimized based on power, cost data, and user objectives/priorities.	Can use high-level or detailed system model inputs. Highly accurate performance results. Supports energy and economic analysis/tradeoff activities based on customer's needs and requirements.	Current version does not have system monitoring or control capabilities. These are planned in the future release.	$ - $$	Alternative energy system dealers, designers, installers, consultants, and contractors; Energy auditors and analysts; Architects, electrical engineers, homebuilders, and remodelers; Educators and trainers
CPF Tools	Clean Power Finance	Designed as a complete, lead-to-quote solar sales solution. CPF Tools helps you acquire and manage motivated and solar-ready leads, efficiently estimate and generate job proposals, and easily initiate and track an array of customer financing options. Review Section: #1 #2	Significant administrative time reduction, best-in-class utility rate and solar incentives database (updated daily), solar sales and tools training. Up-to-date and adaptable Web-interface tool with constant feedback/input. Almost real-time information on utility rates, federal and state rebates/ incentive	Limited thermal and energy efficiency functionality	$$	Solar professionals, from integrators to distributors to manufacturer. CPF Tools is designed for solar professionals, and those looking to enter the solar industry
OnGrid Tool	OnGrid Solar	Excel-based application assisting in PV system sizing, pricing and quoting. It enables solar installers to gather a customer's utility and site information quickly and efficiently. It calculates optimum system size, electricity bill savings, system incentives, and system net costs. It then calculates various economic benefit factors and produces a variety of proposals, quotes, and. The OnGrid Tool includes rates, incentives, and tax calculations, and estimates system performance, including all performance factors and shading data. Review Section: #1 #2	Great solar sales and financial software for salespeople, installers, and contractors who want to streamline making reliable, professional proposals. Excel based for easier understanding and manipulation.	Stand-alone operation only	Contact Info	Solar installers, contractors, and salespeople. It is also used by students, teachers, and anyone who wants to learn about the solar industry

[1] $: <$100, $$: $100-$1,000, $$$: >$1,000

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Name	Vendor	Description	Strengths	Weaknesses	Price[1]	Targeted Audience
Polysun	Solar Consulting	Polysun is a renewable energy system simulation software that helps users to configure and optimize solar and heat pump systems. Applicable to both residential and commercial energy systems.	Large customizable component catalog. Quick simulation time (typically < two minutes). Especially good for solar thermal simulation and heat pump simulation.	Limited to grid-tie PV systems	$ - $$ - $$$	Engineers, designers, component manufacturers
Solar Rater	Earth Science Agency, LLC	Solar Rater app for Android devices makes it easy to determine the solar energy potential for any location on Earth, and calculates the appropriate size for a photovoltaic (PV) system at that location. Key features include: Automatic location detection with GPS, Wi-Fi, or cell tower identification Automatic orientation detection measures the azimuth and pitch of solar panels Automatic magnetic declination conversion gives azimuth based on true north Automatic solar radiation determination based on location and orientation (model result) Outputs the appropriate size of a PV system in DC Watts Data can also be entered manually for offsite use Great teaching tool for novices Accurate results for solar energy professionals Outputs environmental benefits (e.g., greenhouse gas emissions, water saved, trees planted) Saves projects and emails results Street address can be automatically detected or used to look up latitude and longitude Calculates space requirements and cash payback period from user input.	Ultra portable, easy to use, gives immediate and accurate results, free and low-cost versions available; should be used for quick onsite evaluations by solar professionals and facility managers	only works on Android devices; inability to look up specific solar panels and inverters	$	Solar energy professionals and facility managers

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Name	Vendor	Description	Strengths	Weaknesses	Price[1]	Targeted Audience
Solar Shoe Box	ArchiPhysics	Simple to use interface for EnergyPlus. Creates a rectangular model (shoebox) of a direct gain passive solar building. Review Section: #1	Easy to use	Still in development.	free	Anyone interested in passive solar buildings and EnergyPlus

Smart
Data Center Revolution

New Opportunities to Control Costs and Increase Strategic Advantage

SUSTAINABLE SILICON VALLEY

GROWTH WILL CONTINUE

As more business processes and transactions are conducted over networks, the demand for data-center services increases. This, coupled with the spread of virtualization and increased adoption of new operating models, including cloud computing, has forced IT management to focus on optimizing network performance characteristics such as availability, reliability and speed. Thanks to the explosion of smart phones and tablet computers, more devices are connecting to the network every year than were connected in total in 1999, during the height of the dotcom boom.

It is estimated that because of server efficiency, and other factors, technology densities have increased more than 20 times in the last decade. More endpoints (with smaller hard drives) are now conducting more communications with applications hosted on servers. This is shifting application demands from the computer to the server. There is no indication that this trend is going to slow. Much of the increased demand will be driven by **mobile cloud computing**. Consider:

- Smartphones represent only 13% of total global handsets – but 78% of total handset traffic.
- In 2010, 3 million tablets were connected to the mobile network, each generating 5 times more traffic than the average smartphone.

EXECUTIVE SUMMARY

Data centers present multiple challenges – and opportunities, as well.

The challenges? Data Centers use between 1.5 and 2 percent of world electricity with this usage set to grow 12% annually, according to a report published April 2011 by Greenpeace International – and today the lifetime energy expense for powering and cooling data center equipment can cost more than the equipment itself. Companies balancing concurrent demands to optimize performance, control costs and reduce negative environmental impact have to reconsider their data center design and management strategies. Technology refresh rates are accelerating, and along with them equipment and rack densities are outstripping the electrical capacity of traditional buildings, leading to facility obsolescence.

But the opportunities are clear. Data centers are the factories of our age. Plan, build and utilize them thoughtfully and your organization will realize a significant and enduring competitive advantage. This whitepaper will help put your organization on the right path.

AGING INFRASTRUCTURE, WASTED OPPORTUNITY

The last significant upgrade for many data centers was in preparation for Y2K, and that was mainly focused on the racks and stacks, not the physical facilities itself. The rates of change in technology have only accelerated since then.

In one 2010 study by Gartner on aging data centers, almost 30 percent of respondents indicated that their organizations' newest data centers are seven or more years old. Another more recent study, by IDC, suggests the situation is worse, indicating the average data center is 12 years old. But whatever the age of your data center, your organization will likely face the following issues:

- How can we identify what is antiquated in our data centers?
- Steeply climbing demand for computing resources.
- Rising rack densities.
- Rapidly rising power requirements.
- Increased cooling requirements.
- Inflexible, non-scalable legacy designs not focused on efficient management of power and cooling.
- New availability challenges and the increasing need for 2N redundancy.
- Overburdened capital sources.
- Increasing year over year operating expenses.

[1] "The Benefits of Datacenter Transformation with HP", Michelle Bailey, 2009, source2: "Extending the life of your existing data centers", IBM Global Technology Services, June 2009 . "IDC Report suggests that the average age of a data center in the U.S. is 12 years": Source - http://h20427.www2.hp.com/campaign/techatwork/au/en/taw09post/pdf/dct/idc_whitepaper_the_benefits_of_data_centre_transformation_with_hp.pdf

- Mobile data traffic will increase 26-fold between 2010 and 2015.
- Two-thirds of the world's mobile data traffic will be video by 2015.
- There will be 788 million mobile-only Internet users by 2015.
- In context, this means that mobile data traffic will grow from 0.24 Exabytes in 2010 to 6.3 Exabytes in 2015, or just over 6 million Terabytes (most of it mobile video).

– Source: Data Center Knowledge, February 7, 2011

Note – Exabyte (from Wikipedia): An Exabyte (derived from the SI prefix exa-) is a unit of information or computer storage equal to one quintillion bytes (short scale).

QUANTIFYING THE HIGH COST OF AGING DATA CENTERS

As recently as 2008, The Uptime Institute reported that "Unless they have unlimited access to money, senior IT executives can no longer ignore [data center] power and cooling costs."[2]

According to the June 2007 EPA Energy Star Label report, energy consumption in the industry, already $4.5 billion annually, is expected to nearly double over the next five years.

Unless a data center is new or nearly so, the energy costs of IT are becoming an increasing challenge.

- Buildings unfit to handle forklift upgrades, power delivery and rack-level flexibilities.

Exacerbating the issue is the fact that much of the energy consumed in a data center is wasted, thanks to older designs developed when data center power and cooling were only minor considerations for most enterprises.

> Typically only about half the power entering the data center is used by the IT equipment. The rest is expended for power conversions, backup power, and cooling. Peak power usage for data centers can range from tens of kilowatts (kWs) for a small facility, to tens of megawatts (MWs) for the largest data centers (EPA 21). Indeed, server hardware is no longer the primary cost component of a data center. The purchase price of a new (1U) server has been exceeded by the capital cost of power and cooling infrastructure to support that server and will soon be exceeded by the lifetime energy costs.

– The Data Center Energy Forecast Final Report, 2008, Silicon Valley Leadership Group and Accenture

IS YOUR DATA CENTER OBSOLETE?

Understanding and identifying data-center physical-plant obsolescence is important as a first step in making the right data-center decisions. This understanding informs the value chain that your organization will require for increased performance, cost containment and future scalability.

The key is identifying aging mechanical and electrical systems. Unless your data center is new, and built to the most modern standards, it is already struggling to keep up with the demands of high-density racks. The following components are most often affected.

Hardware: Servers, storage and network equipment are all becoming denser, using more power in less space and requiring more cooling to maintain optimal performance.

Power and power distribution: Power systems include power generation equipment, power distribution units (PDUs) for conversion of incoming power and passing it around, switch gear, remote power plugs, uninterruptible power supplies and redundant power systems. In addition, rack distribution adds additional configuration and infrastructure requirements.

[2] Kenneth G. Brill, Executive Director of the Uptime Institute

Older data centers, unable to support the energy demands of new blade servers or of backup power and cooling, have become obsolete. In many cases it is not technically possible to retrofit them to meet configuration and power demands for advanced data centers – and even when it is, the cost, with energy consumption factored in, is prohibitive.

With the aging of the data-center plant come environmental and economic burdens.

"More new datacenters are being built while old datacenters are being retrofitted with new, more efficient datacenter infrastructure. IDC attributes much of this datacenter growth to wholesale datacenter providers and hosters."

– Katherine Broderick, Senior Research Analyst, IDC's Enterprise Servers and Datacenter trends – Nov 15 2010.

POWER USAGE EFFECTIVENESS

Power Usage Effectiveness (PUE) is a measure of how efficiently a computer data center uses its power; specifically, how much of the power is actually used by the computing equipment (in contrast to cooling and other overhead).

Mechanical Systems: This includes air handling and heat-dissipation systems and their designs: chillers, hot and cold-air containment systems, and air and water economizers (outside air or evaporative systems, the ability to use recycled water).

Difficult but necessary questions

Data center users, operators and owners need to consider the following questions:

- How can we identify what is antiquated in our data centers?
- How do we understand what equipment has expired and what is non-serviceable?
- In auditing our current data-center environments from a cost and performance perspective, what are the right choices that position our organization to enjoy financial and performance benefits today?
- What will be our future performance and energy requirements?
- Will the data center we build today be ready for an upgrade to meet future demands when the time comes?
- Will there be limits to resources such as water for cooling?
- Does our design optimize resource efficiency and performance?

Basic indications for assessing obsolescence

Today, the largest variable cost associated with a data-center budget is devoted to heat dissipation and power. As a percentage of budget, this will rise significantly over the next three to five years, as energy costs and equipment energy-intensity increase.

Some of the factors to consider:

Power Gear – Generation and distribution of power has changed rapidly over the last 10 years. New methods like flexible rack-power delivery (10kW to rack 1, 20kW to rack 2, etc.) and vertical scalability (the ability to increase density and consumption without adding square footage to your cage) are important keys to taking advantage of current and future efficiencies. (Note that the typical rack is on a footprint of tiles about two feet square and that measuring kilowatts per square foot is a gross data-center capability measure.) Older infrastructures are not able to scale to current power requirements and cannot offer flexible solutions.

Unfortunately, components like PDUs or uninterruptible power supplies are not modular. In most aged properties, you cannot simply replace a PDU or a

PUE is the ratio of total amount of power used by a computer data center facility to the power delivered to computing equipment. PUE was developed by a consortium called The Green Grid. PUE is the inverse of Data Center Infrastructure Efficiency (DCiE). An ideal PUE is 1.0. Anything that isn't considered a computing device in a data center (i.e. Lighting, Cooling, etc.) falls into the category of facility power usage. New Green Grid PUE standards will include office/restroom areas as well, putting more pressure on PUE ratings.

$$\text{PUE}=\frac{\text{Total Facility Power}}{\text{IT Equipment Power}}$$

WHAT DOESN'T WORK

Consider one data-center provider that has some 70 data centers in the U.S. More than half cannot scale over 100W/sq.ft., nor does the design of the facilities permit vertical scaling.

Or consider the case of a major oil and gas company that runs 70 percent of its business at about 100kW/sq.ft. The remaining 30 percent is over 30kW/rack. There is no standardization per rack; power requirements are different for different racks. An efficient power-delivery system would not require every rack to consume equally but would allow for variable delivery and consumption and provide UPS with a new one. The downstream components would not cooperate; you would have to start over. This brings up a serious issue: older properties lock inefficiencies into their systems.

Heat Dissipation – New designs in cooling employ environmental economization techniques, refrigeration technologies, penthouse cooling designs and filters capable of using recycled water. Their efficiency exposes the drawbacks of current systems never designed for replacement or upgrade. Efficient equipment and flexible designs for refresh and upgrade can lead to significant energy savings.

For a more complete checklist see Appendix 1 or the complete report from the Department of Energy: Best Practices Guide for Energy-Efficient Data Center Design, Revised March 2011, U.S. Department of Energy, Energy Efficiency and Renewable Energy, Federal Energy Management Program (www.eere.energy.gov/femp/pdfs/eedatacenterbestpractices.pdf)

THE COMING POWER SURGE

Historically, commercial office building power supply is about 100 kW/sq.ft. Current enterprise data center users consume 125-150 kW/sq.ft. This will escalate to over 200 kW/sq.ft. over the next three to five years. A rack generally consumes 3-4 kW. This will increase exponentially to more than 30 kW over the next several years. These increasing demands for power illustrate the importance of using the most effective system designs today – and the ability to accommodate enhancements over the life of the building.

The bottom line? According to some estimates, up to 80 percent of data centers are irreparable or would require cost-prohibitive investment to handle future electrical and air conditioning loads.

THE INFLECTION POINT HAS ARRIVED

What happens to enterprises with restricted capital budgets that are trying to migrate from less-powerful legacy gear into more dense environments? How scalable is your data center's power and power redundancy infrastructure? How modular would it be in accommodating change?

Every organization works to optimize its mission-critical value-creation activities. For example, auto companies excel at design, supply-chain management, production and sales. Other supporting services such as IT and facilities have been considered cost centers whose operating costs need to be minimized, with capital budgets that are constrained.

But as more business processes and transactions are conducted electronically, IT and data-center management become mission critical variable redundancy. Effective operational management would be able to cycle power too. Knowing when and how to turn off power is a strong savings source.

WHAT IS WORKING

Yahoo! Lockport, New York, Data Center

Yahoo! operates one of the world's most energy-efficient, environmentally friendly and cost-effective data-center buildings in Lockport, New York. It uses a combination of innovative data-center design and Lockport's naturally cool climate to dramatically decrease its electricity use throughout the year.

The Lockport facility includes the first implementation of Yahoo!'s green data-center design, called the Yahoo! Computing Coop (YCC). The facility uses a combination of climate, prevailing winds and hydropower to keep the 120-by-60-foot server buildings cool.

The YCC design, dubbed the "Yahoo! Chicken Coop," mimics the long, narrow design of a chicken coop to encourage natural air flow 100 percent of the time, resulting in an annualized average of less than one percent of the buildings' total energy consumption being required to cool the facility. It is among the most efficient data centers in the world, with a low PUE of 1.08, compared with the industry average of 1.92.

to business operations in such diverse fields as retail, healthcare, financial services, manufacturing, government and transportation. Data services repo are the source of competitive advantage to be optimized, not a necessary cost to be reduced.

Companies that recognize this shift understand the value of optimizing data-center performance across the enterprise. They encourage collaboration among facilities, IT and business operations functions and technology vendors to make certain that data storage and processing provide sufficient capacity and performance, while managing energy demands and costs. Breaking through organizational silos is key to realizing savings for operating costs.

Visionary companies have come to understand that data centers are now the production systems of the information economy. That is why the old management strategies around data centers will no longer work. Companies that optimize data center services across the enterprise can realize dramatic performance and cost advantage over those who operate in the traditional way. For many organizations, the inflection point has arrived. It is time to act, or be left behind.

TRANSITIONING TO AN ADVANCED DATA CENTER

In times of tight fiscal controls, executives must carefully weigh the trade-offs between capital expenditures intended to reduce operating costs and ensure optimal performance vs. leasing state-of-the-art services from a data-center provider.

Either way, moving to an advanced data center model requires an unprecedented level of cooperation across the organization. Silos must fall. The required expertise includes facilities, IT, hardware, security, software and power management. Because of the complexity of the undertaking, and also because of the potential business benefits, organizations with data centers on the path to obsolescence are turning to data center developers. The right developers – those with experience and expertise – can guide an organization in its quest to reduce capital costs while overhauling existing IT systems.

The most advanced data-center developers combine green building design and other advanced data and energy management solutions to significantly reduce energy consumption, thus dramatically improving Power Usage Effectiveness (PUE) and Data Center Efficiency (DCE).

– *Source: Yahoo! Press Release, "Yahoo! Opens State-of-the-Art Data Center in Western New York", September 20, 2010.*

Sybase, Inc., Dublin, California Data Center

The Sybase, Inc., Dublin, California Data Center saves $262,000 annually, according to company figures.

Sybase determined that the following eight energy-saving measures were practical based on estimated implementation costs and payback periods.

Cooling Plant:

- Utilizes a high-efficiency base-load chiller and cooling tower with VFD fans and temperature/humidity (enthalpy) controls.
- Individual controls optimize chiller loading for various chiller run scenarios as each chiller has different efficiency curves.

Air Management:

- Perforated tiles were relocated to where needed or replaced with solid tiles since "closed" adjustable tiles leak about 35 cubic feet per minute. Tile dampers were adjusted to match rack airflow requirements.
- Raised floor penetrations were sealed, as were cableways, conduits, equipment stands, and ramp skirts.

Customers of these providers benefit from:

- A lower cost for data-center services.
- Brand benefits that accrue from contracting with environmentally responsible suppliers.
- State of the art security.
- Insurance against the risk of rising energy and real estate prices.
- Protection against interruptions to their power supply.

In addition, they can avoid the cost of significant capital upgrades or replacement of aging and obsolete data-center facilities.

These data-center leaders are not just managing each facility's data center to minimize costs. They also look for energy management and server design and layout solutions that optimize data-center performance across the enterprise. They assemble staff from facilities, information technology and the primary internal data-services customers, to provide superior performance with the necessary level of availability, security and system resiliency.

There are other considerations as well. For example, management must also carefully measure the cost of implementing new data-center management practices and equipment against contracting with a specialist who will deliver services using advanced IT equipment, software and energy management practices. Increasing energy costs and potential shortages form an additional risk factor as data-center usage grows exponentially and customers expect round-the-clock service.

DATA CENTER DESIGN CONSIDERATIONS

Considerations such as energy efficiency and life-cycle costs are often neglected in the pressures of operating IT facilities within tight budgets and expectations of high availability.

When data centers are housed in typical office space, the energy demands can overload electrical wiring for the building and put significant strain on the electrical grid system, requiring extensive, time-consuming permitting and retrofitting.

The state of the art for advanced, smart data centers combines mastery of a number of systems. Designing and operating data centers to achieve peak performance and optimum energy efficiency requires balancing server intensity with cooling and back-up power supply requirements. Efficiencies can be realized through energy-sipping hardware, virtualization and demand-management software, layout and building designs that optimize natural airflow of the site, use of recycled or groundwater, and other energy-reducing features.

- VFDs were installed on all 20 CRAH units and created four zones for pressure feedback control. This reduced fan power by 83 percent to remove the same heat.
- Flow diverters were installed on the discharge side of racks with the highest airflow or temperature, reducing impact on the next lineup's intake temperatures (back-to-front lineup arrangement).
- An enthalpy air-side economizer was installed that ducts air into the space. The economizer also serves as emergency cooling system. Added heat recovery to the economizer to heat other spaces.
- Blanking panels were installed inside racks, a key measure.

Lighting:

- Unnecessary lighting was eliminated by using the building management system to control lights from local switches with a 30-minute countdown.

After implementing the energy-saving measures, Sybase energy managers applied Department of Energy's (DOE) DC Pro software tools to confirm the accuracy of the predicted savings estimates. They found:

- An estimated power usage effectiveness (PUE) of 1.35 for a DCiE of 74 percent. The actual measured PUE is 1.41 (DCiE=71 percent).

> "Currently, the typical 3-year cost (operating expenses + amortized capital expenses) of powering and cooling servers is approximately 1.5 times the cost of the server hardware itself, and the projections for 2012 go much higher. Energy efficiency measures are thus of high importance for data center designers, operators, and owners."
>
> *– Source: Kevin Normandeau, Data Center Knowledge, February 4, 2011*

Optimal data center designs will reduce infrastructure expenditures and will also, importantly, reduce the environmental footprint. Carbon emissions, total power consumption and water use by the data center are all positively affected by these advances.

THE SMART DATA-CENTER REVOLUTION

The challenges inherent in an aging data-center plant indicate that data centers should be designed to meet requirements for scalability and efficiency now and in the future. Designs that marry building and IT system design will tend to produce better financial and operational performance. Here are some best-of-breed attributes.

- **Current standards:** The data-center facility should be built (or refurbished) to the highest Energy and Environmental Design (LEED) standards and designed to support significant functionality. If so, the building will be efficient in its use of energy and water (including recycled water) for heating, cooling and other purposes. It will also be able to handle the power requirements of modern servers.
- **Collaboration:** While cross-functional collaboration within the company is necessary, it is also vital to reach out to equipment and software vendors and engineering consultants. This will insure an integrated design that optimizes performance while minimizing resource costs.
- **Latest construction techniques:** Modular construction facilitates data-center upgrades and retro commissioning. On-site electrical substations with the option of variable power ranging from 150 to 500W/sq. ft. are best. It is important to consider backup electricity sources, either renewable or other options. A portfolio of energy sources to supplement (or replace) electricity from the grid helps keep the data center running with predictable energy costs and availability.

- The data center was over-ventilated by almost 130 percent prior to the retrofit but has now been reduced to 30 percent.

– Source: DOE Case Study http://www1.eere.energy.gov/industry/saveenergynow/pdfs/45814.pdf DOE/GO-102009-2850 July 2009

Google Data Center

Google claims a PUE of 1.25 (trailing 12-month average) using a number of interconnected features, including evaporative water-cooling towers, an efficient substation, a chiller ameliorated by use of plate and frame heat exchangers with low-approach temperature characteristics, and thermal storage tanks.

It optimized power distribution and use of high-efficiency transformers and UPS. It also raised thermostat temperatures, enabled by airflow management. Additional systems include fire detection and suppression, fresh-air supply and others. The principles Google used in its container data center can be used in most data centers today.

– Source: Video released by Google, April 8, 2009

Vantage Data Centers

A more recent entrant to the efficient data-center market is Vantage Data Centers. The first Vantage building came online in early 2011, in Santa Clara, California.

- **Minimal power conversions:** The number of power conversions in facility-level power distribution should be minimized. Up to a third of the total energy consumed by a typical server is wasted before reaching the computing components. The majority of these losses occur when converting one kind of electricity, or transforming voltages. The power supply, which converts the AC voltage coming from a standard outlet to a set of low DC voltages, is where most of the energy is lost.
- **Flexibility:** Variable power to the rack is also important. The guiding principle is that solutions will vary for different users, and will also vary according to the demands of the business.
- **Beat the heat:** Heat dissipation both in cooling and containment (where all the hot air is captured in one place to be vented or cooled) needs to be highly efficient. Containment of hot rack air allows for more effective and cost-efficient neutralization. Air-side and water-side economizers and mechanical supplementation reduce resource use and cost for heat dissipation.
- **Tap into local water:** Data centers also must be optimized for water use. This includes use of adjacent water sources when available and the ability to optimally use recycled water.

GOING GREEN ON A BUDGET

Cleantech, a market intelligence firm, forecasts that by 2015, global investment in energy efficient data center technologies will represent 28% of the $150 billion data center infrastructure market.

"The green data center has evolved in response to concern over energy use, but it is also connected to the broader transformation that data centers are undergoing," says senior analyst Eric Woods. "Data centers of the future will be more energy efficient, more adaptable to new business needs and new technology opportunities, and virtualized to ensure optimal use of IT resources, space, and energy."

A new standard to help data centers reduce their energy consumption, operating cost, and enhance their competitiveness was recently introduced by the Singapore Standard for Green Data Centres. It was jointly developed by the Information Technology Standards Committee (ITSC), the Infocomm Development Authority of Singapore (IDA) and SPRING Singapore. Public reports indicated seven public and private organizations – including 1-Net, the National Library Board, SingTel, Resorts World Sentosa and IBM – have already adopted the standard. The standard specifies the need for the commitment of management, clearly defined roles and responsibilities within organizations for implementing green data centers and clearly defined green policies as well.

Vantage coined the term "Smart Data Center Revolution" to commemorate the launch of its Santa Clara campus, the largest LEED® Platinum candidate data center project in the U.S. Vantage architects, builds and leases wholesale data centers for large enterprises and service providers, with unprecedented efficiency, scalability, flexibility and TCO.

With a total campus capacity of 37MW of effective IT power, plenty of growth space is provided, allowing for the widest variety of product sizes on the market. The company's large "standard" 3.0MW suites are designed to encompass modern data center requirements and avoid the pitfalls inherent with inefficient and expensive 20th – century Performance Optimized Data Center (POD) container and shared-facilities architectures.

Vantage's strategy is based on integration of green-building design principles and the most advanced data equipment and supporting infrastructure. Many current wholesale and midpoint data centers offer a one-size-fits-all-approach. In contrast, smart-data-center wholesalers such as Vantage deliver flexible functionality and modular design to provide customers optimized solutions from IT, cost and environmental perspectives.

Enterprise demand for green data centers will drive supply

By Liau Yun Qing, ZDNet Asia on March 31, 2011

http://www.zdnetasia.com/enterprise-demand-for-green-data-centers-will-drive-supply-62208164.htm

VERTICAL SCALABILITY – A NEW DIRECTION FOR GROWTH

Many data centers today severely underutilize floor space because they cannot scale as power densities increase, forcing occupants to prematurely knock down walls or to build another data center.

With vertical scalability, operating costs can decline (relative to traditional data centers) as power densities increase. Scaling vertically in a highly efficient data center can have substantial financial and operational payoffs, including minimized disruption and reduced operating risk.

Rack densities are estimated at around 60 percent globally. This is a consequence of new equipment densities exceeding available heat-dissipation capacity and of the scale to which existing data centers were designed. With better heat-management practices, more servers can be handled in a given building footprint.

New data-center designs allow for rack densities nearer 85-90 percent. But as the compute power per square foot goes up, so do heat dissipation requirements and requirements for compute device per kilowatt. A server uses the same power at 15 percent utilization as it does at 55 percent utilization. Reducing the number of servers, increasing the density in the rack and increasing utilization impose a demand for flexibility that aging infrastructures cannot provide.

CFOs and CIOs are faced with the dilemma of how to provide computing power to meet business demands without being subject to excessive costs for technology, energy or energy-management measures.

The Power of Partners

Vantage credits the development of its next-generation solutions to its partners. Toshiba implemented new technology for hyper-efficient UPS and served as a central purchase point, driving down prices. Both efficiencies accrue to customers.

Fujitsu Biometric Security Systems, GE, and Rosendin Electric all combined their expertise and vision in building the Vantage solution.

CONCLUSION

As data centers increase in importance and complexity, it will become crucially important to plan for increased performance, cost containment and future scalability. With those attributes in mind, organizations will forge a path toward newfound competitiveness, increased revenues and a strong presence in the global economy.

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Sustainable Silicon Valley is a consortium of over 120 business, government, academic and non-profit institutions working together to build a sustainable economy, a healthy environment and an engaged community. Partners are innovators from all sectors who are creating a nationally recognized model for regional collaboration on sustainability and accomplishing breakthrough results for environmental, economic and social resilience.

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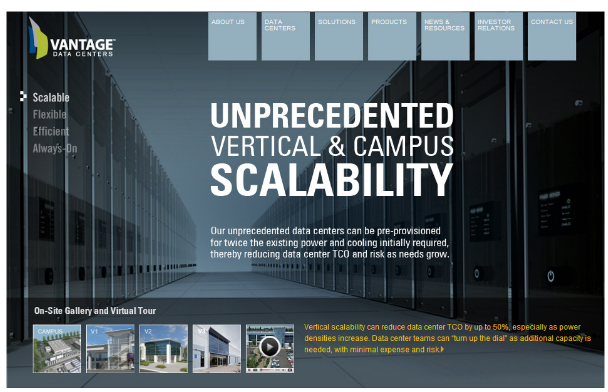

Vantage Data Centers specializes in creating modern computing space, offering state of the art wholesale data center services: plug and play space, with power and cooling. The customer installs the equipment – servers, routers, and switches. Vantage offers superior Power Usage Effectiveness (PUE) and cost effective performance.
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Smart Microgrid Network: Transitioning To A Dynamic Distributed Smart Energy Infrastructure

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SUMMARY

This paper analyzes the current development of the Smart Grid in the United States and evaluates strategies for its deployment, ranging from a utility-centric evolutionary model to an intelligent interconnection of smart microgrids while exploring costs and benefits of different approaches and pointing out trends and challenges. It also examines financial investments required for this transformation while surveying investments that are being made by government, academia and industry, and summarizes key strategies that should be put forth in motion in order to realize a fully functional smart grid that is a balance of two diverse approaches.

INTRODUCTION

The Smart Grid is an evolutionary transformation of the existing electrical network into a much more reliable, highly secure, efficient and adaptable network that is able to utilize renewable energy resources and that enhances consumer choice and convenience while enabling the optimal usage of electricity.

The Smart Grid has been defined differently by different organizations and entities. Some definitions consider smart grid deployment to happen centrally in a top-to-bottom fashion or, alternately, in decentralized, bottoms-up manner. For example the Electric Power Research Institute's (EPRI) report to the National Institute of Science and Technology (NIST) for the interoperability standards roadmap [1] defines the Smart Grid as the modernization of the existing electricity delivery system so that it monitors, protects, and automatically optimizes the operation of its interconnected elements from the central and distributed generator through the high-voltage transmission network and the distribution system, to industrial users and building automation systems, to energy storage installations, and to end-use consumers and their thermostats, electric vehicles, appliances, and other household devices.

SMART GRID – AN INTERCONNECTION OF SMART MICROGRIDS

Our vision of the Smart Grid starts with the MicroGrid, a semi-independent electricity network at a micro scale that contains within it local sources for electricity generation, transmission and distribution, mirroring essential components of the electricity network at a smaller scale. Such a microgrid can be envisioned to be smart when it deploys renewable resources for generating electricity for its local domain, rations electricity onsite using novel means like electric vehicles for daylight charging, offers consumers flexibility in supply and pricing to adapt to their demands and the ability to sell back electricity to the grid, while being intelligently interconnected to other microgrids and to the utility for supplementary energy transactions. A dynamic interconnection of such individual or clustered Smart MicroGrids forms the fabric of a truly smart electricity grid.

A smart grid only driven by Utilities extends the monopoly framework with smart meters and other smart technology, such as switches. Knowledge still tends to flow from consumer to utility and does not flow across the system bi-directionally. Consumers are not still fully empowered to make choices and the emphasis is on a smarter medium of transmission and distribution while omitting smart endpoints – the consumers.

A smart grid comprised of a dynamic network of smart microgrids as shown in Figure 1 is based on a democratic framework where consumers are empowered through technology and through tariffs and regulations to understand and manage their own energy use and production locally, selling energy back to the grid, providing storage services through fuel cells and electric vehicles and providing demand response services. This type of grid is characterized by distributed renewable energy matched to and located nearby demand, with the grid being a source of supplemental power and storage. It is also characterized by dynamic market pricing that rewards conservation, enables production of electricity from local renewable sources and allows non-utility producers to compete in providing electricity, metering, and smart energy management services. A truly smart grid would consist of a network of smart microgrids, collaborating regionally to address maximum energy demands from local energy sources while promoting energy efficiency and conservation.

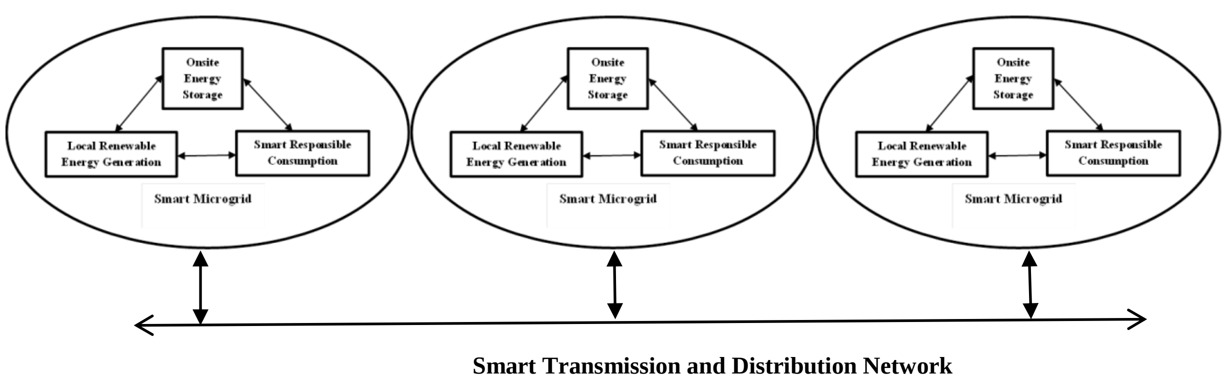

Figure 1: Smart Microgrid Network

A BALANCED APPROACH

A balanced combination of these two models (a top-down approach of upgrading the existing distribution network and bottom-up approach of deploying a dynamically interconnected smart microgrid network) will ultimately be necessary to sustainably continue driving the smart grid model during and after its deployment. While a decentralized approach will drive faster implementation and bring in innovation and differentiation beneficial to the consumer, a centralized government drive will be equally important in monitoring minimum quality of service for electricity and for maintaining reliability of the network during its life cycle, as well as for defining and evolving interoperability and standardization of various interconnection interfaces of the smart grid. This is perhaps analogous to the development of wireless networks or of the internet, where standardization defines interoperability yet operators are free to compete and develop various implementations, offering differentiated and customized services to the user.

CURRENT INFRASTRUCTURE, COSTS AND LIMITATIONS

The electricity delivery system today is centralized, linear and unidirectional. A central power plant generates electricity, a transformer steps up the voltage for transmission, transmission lines carry electricity over long distances, a transformer steps down the voltage, distribution lines carry electricity to houses, transformers on poles step down electricity before it finally enters houses [8].

This unidirectional flow of electricity in generation, transmission, distribution and consumption is embedded in the infrastructure today and offers resilience to an evolution into a networked consumer-friendly smart grid. A smart grid, in complete contrast with existing infrastructure, requires electricity and information to flow bi-directionally between the power plant and user, to provide feedback of the flow at every level, and to provide monitoring capabilities, robustness, security, flexibility and adaptability.

Most centralized power plants today are about 35 percent efficient and use steam turbines, internal combustion engines, gas combustion turbines, water turbines and wind turbines to generate electricity [8]. There are more than 10,000 transmission substations and 3000 distribution substations in the U.S. [9]. Substations are critical components of the electricity delivery system and a loss of only 4% would result in 60% loss of connectivity in the grid [8].

While such losses can go undetected for a period of time in a conventional electric grid resulting in extra cost, a smart grid based off an interconnected system of smart microgrids would be able to detect and correct such losses dynamically and thus save on costs.

COSTS FOR UPGRADING EXISTING ELECTRIC NETWORK

A useful data point is to analyze the cost of upgrading the existing electrical infrastructure and to compare it to financial investments required to move towards a smart microgrid based network. Table 1 shows some typical capital costs for upgrading existing electric transmission lines, by voltage (2006 data).

Transmission Facility	Capital Cost ($ per mile)
New 345 kV single circuit line	915,000
New 345 kV double circuit line	1,710,000
New 138 kV single circuit line	390,000
New 138 kV double circuit line	540,000
Single Circuit underground lines	Approximately 4 times the cost of single circuit lines
Upgrade 69 kV to 138 kV line	400,000

Table 1: Typical Capital Costs for Electric Transmission Lines, by Voltage

Source: National Council on Electricity Policy, "Electricity Transmission: A Primer", June 2004, from U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability [8].

A recent report in 2011 by Visiongain Research [10] has evaluated the level of capital expenditure in the existing electric power transmission and distribution equipment market, showing that the market is worth $128.9 billion in 2011.

COSTS OF BLACKOUTS AND OUTAGES

Another cost element associated with the current infrastructure consists of blackouts and outages cost. According to an EPRI report [11] the cost of a massive blackout with the current infrastructure is estimated to be around $10 billion per event. Other EPRI studies [12] have estimated the cost of power disturbances across all business sectors in the U.S. at between $104 billion and $164 billion a year as a result of outages. Another $15 billion to $24 billion has been estimated to be because of power quality issues.

A smart grid that is based off an interconnection of smart microgrids will prevent or greatly reduce the possibility of blackouts and prevent such financial losses using macro-monitoring, self-adjustment and local-generation capabilities.

BENEFITS OF A SMART GRID

The goals of a smart grid are to provide quality, reliability, security and adaptability in the transmission and distribution of electricity while enabling efficiency in generation and consumption. The smart grid creates new paradigms of smart energy generation and smart users. Many studies like [1] and [2] further elaborate and describe these goals.

Smart microgrid benefits include greatly reduced carbon and other GHG emissions as generation is based off solar, wind, fuel-cells or biomass deployed en masse, and the evolution of urban structures [7] that are able to combine heat and power (CHP) and employ efficient design principles in their construction. Using the smart microgrids approach enables the transformation of cities towards sustainable islands or clusters. The interconnection of these pockets together with an evolved, smart and automated transmission and distribution electricity network based on feedback makes up the eventual smart grid.

An induced incubation and growth of the smart microgrid model in a decentralized environment also fosters investments by the industry and is of key advantage to ecology itself as it finds new benefactors who promote sustainability while continuing to derive profit. The ultimate gain is to our planet.

These goals also suggest that achieving a complete Smart Grid transformation will require a major overhaul of our existing unidirectional power delivery systems along with considerable financial investments in order to realize a fully operational Smart Grid.

SMART GRID TRANSFORMATION – KEY PLAYERS

Conventional key players responsible for investing in and shaping the transformation of today’s electricity grid into a sustainable smart grid include the government, utilities, and various companies (for example, startups or big networking companies) that can create differentiated solutions and infrastructure for enabling a smart grid and that can sell their solutions either to utilities or directly to consumers.

The interconnected smart microgrid model also introduces new entrants at the grassroots level like universities, local municipalities, and companies that research, develop, deploy and demonstrate the feasibility of smart microgrids. Finance for such a model will come from grants, from VCs and from bigger companies. Going forward what is important for commercializing the smart microgrid approach is that the free market concept is allowed to flourish with appropriate regulatory balance, so that private non-utility companies are able to see value in pursuing this model in terms of profits that they can make upon investing. This is a challenging prospect for the government, utilities and IOUs given the traditional centralized nature of the electricity network but it is a critical policy piece that needs to be incorporated for driving the smart grid transformation in an innovative bottom-up manner.

PROJECTED TIMELINES FOR SMART GRID DEPLOYMENT AND GROWTH

Many studies like Electric Power Research Institute (EPRI) 2011 report [2] seem to suggest that the time taken for a smart grid transformation will range from 15 to 20 years or more. For example a 2011 report from the National Science and Technology Council (NSTC) [3] suggests that "Building a smarter 21st century grid is a process that will unfold over years and even decades". In making such generic or specific projections, it is assumed that the transformation will have to be an evolution from the existing infrastructure to what is desired.

Development at a localized level should be faster than the centralized approach, simply because individual communities like Universities or the Military can work much faster and not get limited by regulations or bottlenecks. Projects that demonstrate smart microgrid deployment have timelines of 2 -3 years at most. The advantage of the decentralized smart microgrid approach is that it fosters faster development as independent projects can execute simultaneously, and expansion is limited only by the discoverability and clear establishment of business models that can help commercialize this approach for real life projects. Standardizing the interconnections between smart microgrids will allow for individual development and optimizations to continue as long as the interfaces do not change.

INTEROPERABLE SOLUTIONS FOR DEPLOYMENT

Timeline projections like in [2] and [3] also take into account the development of inter-compatibility solutions and models that will coexist with existing infrastructure as the system transforms itself. Solutions that are able to achieve success using this inter-compatibility approach are seen to be key enablers in achieving the eventual transformation. Many companies like Echelon [4] today illustrate this approach as they interface their networks and smart microgrid solutions with existing utilities and telecom entities by offering solutions like Echelon's IP based Lon network [5]. Fuel cells and smart meters/chargers and systems such as Cisco's mediator also help integrate various proprietary systems to be able to interoperate to manage demand and supply dynamically. Silver Spring Networks [32] also has a unique vertical solution for a feedback based consumer friendly electricity grid.

Along with this inter-compatible evolution, it is also recognized that there can be disruptive technologies, innovations and breakthroughs during this period that can accelerate and spur the growth and adoption of the Smart Grid. Given the state of our mobile and entertainment industry for example, it may be a fair conclusion to expect such innovation to happen in the consumer space, but it is equally likely to happen in the power management domains of the transmission and distribution sectors. Such disruptive patterns or events however are not predictable and cannot be accounted for, so most of the existing literature of estimations and reports will tend to be more conservative than bold in projecting growth patterns for Smart Grid development and deployment in the U.S. [2], [3].

A key challenge today is a lack of technical and interoperable open standardization by the government for different layers that make up a smart microgrid which drives companies like Echelon for example to define their own networking standards for interfacing with the electric grid [5]. Historically such trends in the U.S. have also been seen in the development of wireless networks, where unlike Europe, there was a lack of standardization of protocols which lead independent companies like Qualcomm to adopt and define the CDMA network thereby also ensuring a monopoly by way of intellectual property rights, whereas European countries adopted the method of open standardization for GSM and hence their protocols were more widespread and operator independent [6].

Unless open interoperable standards are formed, for example for energy storage, plug-in EVs, or inter-grid communications what we will see are incompatible vendor solutions that will limit differentiated vertical offerings and a successful wide-scale deployment and adoption of the smart grid. Another drive can come from the Department of Defense if it allows commercialization of technologies deployed for its own smart microgrid project, quite akin to how ARPANET lead to the internet revolution [13].

SMART GRID TRANSFORMATION – COST ESTIMATES

In 2011 EPRI has prepared a report [2] that summarizes the investments needed to create a fully functional smart grid in a top to bottom fashion. While the resulting estimates of this report are still open for debate, it is nevertheless a starting point for analysis of possible levels and areas of investments that will be required in order to transform the current power delivery system into a smart grid.

According to the report, the net investment needed to realize a fully developed smart grid of the future is between $338 and $476 billion. The total benefits that would be realized as a result of these investments would range from $1,294 to $2,028 billion, implying that the benefits would clearly outweigh the investment costs of the smart grid. Benefits have been characterized over a wide variety of areas and elaborated in [2].

The proposed investments [2] are further broken down into the different components of transmissions and substations, distributions and consumer. According to the report the largest chunk of investments are applicable to the distribution network, ranging from $231,960 to $339,409 million. This is followed by investments on transmission and substation improvements, which will range from $82,046 to $90,413 million. Finally, the consumer space will require investment from $23,672 to $46,368 million.

For consumers, estimates have also been made about the percentage increase in monthly electricity bills as a part of cost to support these investments. Analysis show that for residential customers, the percentage increase in monthly bills amortized over a 10 year value will range from 8.4% to 11.8% of their regular bills. This cost goes up a little for commercial customers (9.1% to 12.8%). [2]

This implies that a yearly investment between $17 and $24 billion per year [2] will be required over the next 20 years to evolve our electricity infrastructure into a smart grid. Notably, these costs cover a wide variety of enhancements to the electricity grid, but they exclude the cost of generation, the cost of transmission expansion to add renewables and customer costs for smart-grid ready appliances and devices, essentially costs that are critical to evaluating the development of a smart microgrid.

Predicting the total costs of a smart microgrid based deployment is not easy. While it is clear that big government spending can definitely be avoided with this approach as deployment is piecemeal and individualized, there are also many unknowns in this model today. According to Pike Research data [15], more than 2000 smart microgrids will be operational in 2015, with the microgrid market being segmented and driven into key microgrid sectors or categories like campus based or institutional, commercial or industrial, community or utility, remote off-grid, and military. Other reports that also refer to Pike Research [28], point out that U.S. is well positioned to be a global leader in microgrids, estimating that by 2015, investments to the order of $2.76 billion will have been made that generate 940 MW from microgrids alone.

It is clear that more standardization is needed for microgrids in order to determine an effective cost model for this approach. A challenge for smart microgrid project investors today is to determine what optimal mix of technologies will show the highest returns on investment (ROI) based on customer requirements. For example an operator may choose a judicious mix of solar and fuel cell technologies when creating energy storage solutions for a smart microgrid keeping in mind the ROI for these renewable technologies. Again, a lack of open technical standardization that allows comparisons when projecting the cost and benefits of different technologies for operators not only slows down smart microgrid development but also allows for incompatible solutions to coexist in the market as operators start developing isolated solutions for microgrids today.

For the foreseeable future, without viable commercial investment models in place, microgrid development is expected to be mostly sporadic, individualized and for demonstration or customized purposes, as indicated by University and Military efforts today.

RISING WORKFORCE COSTS

Another cost factor that is overlooked by some reports is the cost of training an entirely new breed of workforce for the smart grid. A 2011 report by Gridwise Alliance [16] indicates that as per 2008, approximately 53% of the electric industry workforce employed by utilities is aged 45 and over. Recent surveys indicate that utilities will need to replace 46% of skilled technician positions by 2015 because of retirement or attrition (Center for Energy Workforce Development 2009 and U.S. Bureau of Labor Statistics 2010). According to this report, new smart grid jobs will continuously be created between 2009 and 2018, where the highest growth is seen in Direct Utility Suppliers [16] with total jobs averaging around 140,000.

During the next 4 years, KEMA's projection estimates a potential disbursement of $16 billion in smart grid initiatives that would catalyze driving associated smart grid projects to the value of $64 billion [16]. The impact of these would be the creation of at least 280,000 new jobs, out of which 140,000 would persist as on-going high-value positions. The associated costs with these jobs is the education and training that will be required to bring the Millennium generation up to speed with new smart grid job requirements.

INVESTMENTS BEING MADE TODAY

Smart grid financing centrally is from three sources – US Government Grants (ARRA), Federal Transmission Tariffs (FERC), and utilities under state PUC authority (in retail rates) [19]. The Energy Independence and Security Act of 2007 [17] and the American Recovery and Reinvestment Act (ARRA) of 2009 [18] are major government initiatives in first recognizing the importance of developing a smart grid infrastructure for the U.S, and secondly in defining channels for allocating grants for smart grid projects.

According to a 2011 government report [3] around $4.5 billion has been reserved as grants for smart grid development by ARRA. The report also exemplifies various local investments, for example, the DOE and BPA invested $108 million in deploying a wide-area synchronized measurement system to monitor high voltage transmission lines that serve many U.S. Western states. Government investments from ARRA at this stage however are mostly for demonstration projects and not for real life projects.

According to a Grid Alliance report [16], the U.S. Department of Energy has, as of July 1, 2011, disbursed $1.252 billion of smart grid funding through its ARRA account by the Smart Grid Investment Grant Program (SGIGP) and a smaller amount of $128.8 million through its Smart Grid Regional and Energy Storage Demonstration Program. These two programs are defined in EISA 1306 and EISA 1304 respectively [17]. ARRA reserves around $4 billion for smart grid grants and also establishes a mechanism of demonstration of smart grid projects by companies that want to qualify for grants. According to [16], the ARRA funds in combination with industry financing bring the projected smart grid investment close to around $8.1 billion.

Another sector investing in smart grids growth is Venture Capitalist funding. According to a recent report by Green Tech Media [20], VC and M&A activities are on the rise. Hundreds of millions of dollars of VC investment is being targeted into a wide range of Smart Grid startups which create new markets and ecosystems, from power generators to home networks to smart appliances. These investments supplement the top-down transformation approach rather than the smart microgrid approach. Key players involved in smart grid M&A include GE Energy, GridPoint, BPL Global and Consumer Powerline among others. VC investments in these companies range from $20 to $120 million (as in the case of GridPoint for Round E investments).

Various reports like [20], [22], [23] and [34] further indicate strong momentum in VC investments. For example, [34] mentions that total VC funding for Q2 2011 was $104 million, with the largest deal of the quarter being a series D $50 million funding for “iControl Networks” by big companies like Cisco, Intel, Comcast. These reports also indicate that companies that provide communication solutions for the smart grid receive highest VC funding, followed by grid optimization and power management solutions.

Money from IPOs can be seen as another form of investment. For example, Silver Spring Networks, one of the most successful smart grid startups, which received Round C funding of around $17 million initially now does an IPO in order to raise capital [21]. Such funds are another source of investment and companies could redirect this capital into channels that continue driving smart grid growth.

CAMPUS LED SMART MICROGRID INVESTMENTS

Another form of investment that is happening is at the grassroots level for the deployment of smart microgrids. Various universities have adopted the model of the smart microgrid for their campuses. Notable among them is University of Santa Clara’s collaboration with Sustainable Silicon Valley, Cisco and Serious Energy in deploying a campus wide smart microgrid [14], [24]. The microgrid currently produces 1 MW from Solar, 2 MW from standby Diesel and generates biogas using garden waste. Using an Energy Management System from Serious Energy, this system also allows the dynamic control of HVAC systems and temperature control. When the smart microgrid starts functioning from 2012 the system will be able to instantly turn off lights and equipment in any building, adjust optimum temperatures for server rooms based on feedback from smart box based sensors, and ration electricity in order to sustain in times of prolonged outages. The campus will also be able to charge Electric Vehicles based on locally stored electricity generated from its smart microgrid.

Another example is the proposed development of a 250 acre 100 MW smart microgrid project for a business park at Moffet Park, launched as an initiative of Joint Venture: Silicon Valley Network's Climate Prosperity Initiative [35]. This is a public private partnership between the city of Sunnyvale, U.S. Department of Energy's Lawrence Berkeley National Laboratory (LBNL), Google, NetApp, Lockheed Martin, Yahoo, Juniper Networks and Infinera Corp. While still in its preliminary stages, the park's objective is to utilize renewable energies, offer grid resource optimization, lower the net carbon footprint of member facilities and create a net zero business area. The project also plans to create a University campus on site (University Associates – Silicon Valley) that will not only teach curriculum but will also showcase net zero carbon footprint. As this is a real life project aimed for new development projects, funding for retrofitting or redesigning these projects will have to come from the companies themselves. Challenges include financing and bringing together multiple building owners with possibly different sustainability goals.

While these grassroots investments for the deployment of smart microgrids are absolutely essential for the transformation into a smart microgrid based society, the next step that will take these developments to the next level is open standardization and viable business models for interconnecting these isolated microgrids together.

UNCONVENTIONAL INVESTMENT TRENDS

The smart grid transformation is also ushering in new investment trends and unconventional players at the time of writing this paper. Rural electric cooperatives and small municipal utilities have started investing in and adopting smart grids [25]. This is seen as a shift and a necessary evolution in the approach for utilities that were earlier focused more on a centralized structure that did not take users into account but are now focusing more on involving the consumer.

According to [25], "Public power utilities are not only leading the way in adopting smart grid technologies, but are also rapidly becoming innovators. Cooperatives have taken steps to develop new modes of interoperability and 30 percent of them are now integrating their smart meter systems with other data systems, such as outage management systems and customer information systems. The National Rural Electric Cooperative Association has launched a Cooperative Research Network that will deploy a ten-state smart grid pilot designed to inform interoperability and cyber-security development."

According to this report, cooperatives currently lead smart meter deployment with 25 percent penetration of their customers' homes—three times higher than the average across all utilities, according to the Federal Energy Regulatory Commission (FERC). Half of all cooperatives offer their customers advanced metering infrastructure (AMI); together they generate 25 percent of U.S. residential peak load reductions, even though they only account for 10 percent of electricity sales. However, smart meters by themselves are an incomplete solution to the smart grid. Utilities will need to work with private companies in defining an ROI model for investments to help deploy a vertical differentiated smart solution for the smart user.

Another unconventional trend concerns some key assumptions in the smart grid concept. These will also be challenged and will have to adapt when tested by the market during deployment. An example of an assumption is in the concept of dynamic pricing [36]. While previous reports that research the benefits of dynamic pricing in the smart grid like the Brattle Group report [26] and the FERC's national assessment of Demand Response Potential [27] estimate that the financial benefits of dynamic pricing may exceed $65 billion by 2030, other reports from IEEE [25] seem to suggest that use of dynamic pricing across the United States is currently flat or declining rather than growing.

According to [25], "despite an 85 percent increase in advanced metering over the past two years, the number of entities offering sophisticated pricing programs has decreased. There are 72 fewer entities offering Time of Use (TOU) Rates programs today than there were in 2008—which translates into 180,000 fewer consumers being offered TOU plans. The decrease in entities offering Real Time Pricing (RTP) is even more dramatic: In 2008, 85 entities offered RTP programs and within only two years this number has shrunk to 19. The pattern is evident not just among investor-owned utilities but among cooperatives as well, whose programs shrank drastically from 20 to only 2 in the same time period."

These reports seem to suggest that concepts and assumptions in the smart grid transformation will be subject to similar market demand and supply forces as any other entry and may not necessarily be only driven by policies and conventional assumptions. Players that succeed in driving the transformation of the smart grid are those that realize the current demand and that adapt and provide solutions that meet these demands in a timely and cost-effective manner.

KEY CHALLENGES FOR THE U.S

Unlike European countries like Denmark or Asian countries like Japan where the smart grid movement has taken greater foothold, the U.S. today lags behind them as per various studies and reports. For example, [28] indicates that highest investments in smart grids are by China, followed by South Korea. Primarily the difference is that the governments of those countries incentivize renewable resources and other smart grid related developments to a greater degree than the U.S. does today and this is partly due to an established system of government subsidies that has been prevailing in those countries historically.

Among unique challenges that the U.S. faces in comparison to these countries is its political system that is based on the concepts of the free market and how to best utilize this model to foster innovation and growth for smart grids, a larger geographical area with lesser penetration of renewable energy resources resulting in comparatively reduced demand and lesser amounts of investments into research programs that drive transformation in those countries. Another factor is the centralized nature of the electricity industry which continues to exist today and prohibits in its current state a full scale expansion or the possibility of large scale commercialization of the smart microgrid.

There has also been negative public opinion in the U.S. on some aspects of the smart grid, for example, backlash against innovative dynamic pricing, health concerns against smart meters, and utilities showing resilience to some concepts that allow entry of non-utility players that can compete in this field. Many reports [2] elaborate procedural, technical and cultural challenges in the U.S. that could be responsible for this negativity. Proper studies can help alleviate such fears or at least present information in neutral manner than can be further addressed.

A key challenge here for consumer adoption is that people are used to the way electricity works for them so there should be very clear and tangible benefits for them to adopt this new model. A smart repackaging of consumer based endpoint solutions with clear advantages can generate demand and desire for optimizing consumption and can help drive disruptive growth in this area.

Another challenge is the lack of establishment of detailed technical standards and interoperability specifications that can allow vendors to offer smart differentiated services to the utility or the consumer. Clear timelines and milestones will also need to be defined for the nation in order to have a substantial movement towards deployment of smart grid. For example reports like [28] indicate that the European Union has mandated 80% penetration by 2020. However, these reports also suggest that while U.S. is lagging behind today, the rate of growth of U.S. investment is on the rise, predicting that of the $200 billion of expected global smart grid investment from 2008 to 2015 more than $50 billion is expected to be in the U.S [28].

Cost recovery or return of investment for various investments that will be made for enabling a microgrid or a smart grid is another concern of individual operators that will also have to be analyzed and addressed. Finally, privacy concerns about a new network that transmits information bi-directionally will need to be addressed, both from individual and national privacy concerns. Many online discussions and survey reports, for example Agrion [29] address these issues while papers like [30] and [31] are also able to holistically compare U.S. and European efforts for Smart Grids today.

CONCLUSION – STRATEGIES THAT WILL WORK

Business models that mesh with existing infrastructure and help commercialization of the top-down approach as they design differentiated solutions will succeed on selling solutions to utilities as well as customers. Key examples are the business models of Echelon [4] and Silver Spring Networks [32] that clearly demonstrate this paradigm. Players that are always cognizant of current demand and provide solutions that meet these demands in a timely manner for a changing landscape and as smart grid requirements evolve are also bound to succeed.

A bottom's up model that starts with the smart microgrid at the grassroots level that consistently demonstrates clear advantages of a microgrid be it in university campuses [24] or around urban buildings [7], not only fosters development and innovation but also helps favorably drive public opinion towards concepts around ecological sustainability. This needs to be driven to the next level by introducing open standards and allowing viable business solutions to exist.

A report published in May 2011 [33] illustrates the advantages of an interoperable approach towards solving the monumental task of a smart grid conversion. Strategies that take existing utilities and telecom providers into account and allow them to vigorously participate in the transformation process while continually evolving the landscape towards a decentralized environment are favorable for implementation as the probability of large scale transformation is higher with such approaches.

Another approach by individual companies is to drive smart grid standardization by defining smart grid special interest groups and consortiums of affiliated companies. This spearheads the smart grid movement and also starts the eventual deliberation process around generic specifications.

Movement from the government is a key factor in enabling large scale growth of the smart grid transformation. By defining open standards, the government needs to allow the development, deployment and commercialization of smart microgrids by the industry. With the recent federal report published in June 2011 [3] that lists how the federal government should approach smart grid deployment in the U.S., there is reason to expect continued momentum in this area as well.

Finally new and unexpected market players (for example rural initiatives, micro-grid players, new special interest groups) will continue to emerge and evolve in this area. Conducive frameworks that allow propagation of newer models and allow fundamental change to evolve will foster innovation and succeed as best strategies for driving the growth of the smart grid.

In conclusion the transformation of the electricity network as it exists today to a fully functional smart grid comprising of interconnected smart microgrids involves considerable financial investment, government led open standardization and timelines, grassroots movement by university campuses, viable business models for large scale commercialization, and positive reviews of newer technologies leading to consumer adoption. With this paper we have attempted to capture all of these aspects of the smart grid transformation in the United States. With the right strategies set forth in motion the possibility of a fully functional smart grid for the nation should eventually become a reality.

REFERENCES:

1. Dollen, Don Von. *Report to NIST on the Smart Grid Interoperability Standards Roadmap*. SB1341-09-CN-0031. Electric Power Research Institute, 2009.

2. Gellings, C. *Estimating the costs and benefits of the smart grid*. 1022519. Electric Power Research Institute, March 2011.

3. Chopra, Aneesh, Vivek Kundra, and Phil Weiser. Executive Office of the President of the United States. *Policy Framework for the 21st Century Grid: Enabling our Secure Energy Future*. Washington D.C. 20502, June 13, 2011.

4. Echelon, "Making the Grid Smarter." *White Paper*. Echelon, 2009. Web. 24 Aug 2011. <http://www.echelon.com/solutions/smartgrid/documents/makingthegridsmarter.pdf>.

5. Tennefoss, Michael R. "Echelon White Paper: Implementing Open, Interoperable Building Control Systems." *Echelon White Paper*. Echelon 005-0137-01A, 2000. Web. 24 Aug 2011. <http://www.enerlon.com/JobAids/BacNetComp.pdf>.

6. Gandal, Neil, David Salant, and Leonard Waverman. "Standards in Wireless Telephone Networks.", *Telecommunications Policy*, Feb 12, 2003. Web. 24 Aug 2011. <http://www.tau.ac.il/~gandal/telecomstandards.pdf>.

7. Marnay, Chris, and Ryan Firestone. "Microgrids: An emerging paradigm for meeting building electricity and heat requirement

efficiently and with appropriate energy quality." *Ernest Orlando Lawrence Berkeley National Laboratory*. Environmental Energy Technologies Division, April 2007.

8. *The Electricity Delivery System*. www.electricity.doe.gov. U.S. Department of Energy - Office of Electricity Delivery and Energy Reliability.
9. Willrich, Mason. *Electricity Transmission Policy for America: Enabling a smart grid end to end.* . MIT-IPC-09-002. Massachusetts Institute of Technology, July 2009. 43.
10. "The Electric Power Transmission and Distribution (T&D) Equipment Market: 2011 - 2021." VisionGain, 03/01/2011. Web. 25 Aug 2011. <http://www.visiongain.com/Report/626/The-Electric-Power-Transmission-and-Distribution-%28T-D%29-Equipment-Market-2011-2021>.
11. "Final Report on the August 14, 2003 Blackout in the US and Canada: Causes and Recommendations." US-Canada Power System Outage Task Force, April 2004. Web. 25 Aug 2011.
12. Primen,"The Cost of Power Disturbances to Industrial and Digital Economy Companies."*CEIDS*. EPRI, June 2001. Web. 25 Aug 2011.
13. Leiner, Barry M., Vinton G. Cerf, David D. Clark, Robert E. Kahn et al. *The Past and Future History of the Internet*. No. 2. Vol 40. Communications of the ACM, Feb 1997. 102-108.
14. "The Power of a Smart Microgrid." *www.scu.edu - Santa Clara University News Center - Featured News and Events*. Santa Clara University. Web. <http://www.scu.edu/news/features.cfm?c=8569>.
15. Enbysk, Liz. "Microgrids: Are They Our Aging Grid's Bail-Out Plan? ." *www.smartgridnews.com*. www.smartgridnews.com, May 25 2010. Web. 25 Aug 2011. <http://www.smartgridnews.com/artman/publish/Delivery_Microgrids/Microgrids-Are-They-the-Grid-s-Real-Bail-Out-Plan-2398.html>.
16. KEMA, "The U.S. Smart Grid Revolution: Smart Grid Workforce Trends 2011." *GridWise Alliance*. KEMA, July 25, 2011. Web. 25 Aug 2011.

17. Sissine, Fred. *Energy Independence and Security Act of 2007: A Summary of Major Provisions*. Summary of P.L. 110-140 H.R. 6 . RL34294. CRS Report for Congress, Dec 21 2007. 27.

18. 111th Congress of the United States of America. *American Recovery and Reinvestment Act of 2009*. Washingdon D.C.: U.S. Govt, Jan 6 2009.

19. Cowart, Richard. *Financing the Smart Grid Project: Costs, Rates and Public Policy*. Madrid: IEA INARD, September 28, 2010. 25.

20. Wesoff, Eric. "Smart Grid VC Investment Surge." *www.greentechmedia.com*. Copyright @2011 GreenTech Media Inc., Jan 21 2010. Web. August 28 2011. <http://www.greentechmedia.com/articles/read/smart-grid-vc-investment-surge>.

21. Fehrenbacher, Katie. "Silver Spring Networks files for an IPO of up to $150M." *www.gigaom.com*. GigaOM, July 7, 2011. Web. August 28 2011. <http://gigaom.com/cleantech/silver-spring-networks-files-for-an-ipo-of-up-to-150m/>.

22. Eboom. "Venture Capital Spills Into Smart Grid to start 2010." *www.energyboom.com*. Energy Boom, Jan 22, 2010. Web. August 28 2011. <http://www.energyboom.com/emerging/venture-capital-spills-smart-grid-start-2010>.

23. Wesoff, Eric. "The Big List of Green Tech VC in July." *www.greentechmedia.com*. Copyright @2011GreenTech Media Inc., August 2, 2011. Web. August 28, 2011. <http://www.greentechmedia.com/articles/read/The-Big-List-of-Greentech-VC-in-July/>.

24. "Smart Grid Case Studies: Clean Energy Strategy - Part of Santa Clara University's Business Continuity Plan." *www.ecocloud.com*. Sustainable Silicon Valley, 2011. Web. August 28 2011. <http://ecocloud-sv.com/page/smart-grid-case-studies>.

25. Fox-Penner, Peter. "Surprizing Deployment Developments." *smartgrid.ieee.org*. IEEE, August 2011 Issue. Web. 28 August 2011. <http://smartgrid.ieee.org/news-smart-grid-newsletter/5599-surprising-deployment-developments>.

26. Faruqui, Ahmad. "*The Case for Dynamic Pricing"*. 2010. San Paulo: The Brattle Group, Inc., August 23, 2010. 33.

27. "Staff Report, Federal Energy Regulatory Commission." *A National Assessment of Demand Response Potential - key assessments regarding demand response for smart grids*. Freeman, Sullivan & Co,The Brattle Group, and Global Energy Partners, LLC. , June 2009.

28. Lowe, Marcy, Hua Fan, and Gary Gereffi. "U.S. Smart Grid - Finding new ways to cut carbon and create jobs." *Center on Globalization, Governance and Competitiveness*. Environmental Defense Fund, April 19, 2011.

29. "Comparison of U.S. and E.U. Regulatory Smart Grid Markets ." *www.agrion.org*. Agrion, March 22, 2011. <http://www.agrion.org/sessions/agrion-int-Comparison_of_US_and_EU_Regulatory_Smart_Grid_Markets_.htm>.

30. Zhang, Zhen. *Smart Grid in America and Europe - Similar Desires, different approaches (Part 1)*. 1799705. Public Utilities Fortnightly (www.fortnightly.com), Jan 2011. 46-50.

31. Zhang, Zhen. *Smart Grid in America and Europe - Past Accomplishments and Future Plans (Part 2)* . 1799722. Public Utilities Fortnightly (www.fortnightly.com), Feb 2011. 32-40.

32. "Silver Spring Networks - The Smart Energy Platform." Silver Spring Networks, Web, August 28 2011 <http://www.silverspringnet.com/solutions/>.

33. Gilbert, Erik, Daniel Violette, and Brad Rogers. *Paths to Smart Grid Interoperability: A Smart Grid Policy Center White Paper*. GridWise Alliance, May 2011. 76

34. "Smart Grid Funding and M&A: Q2 2011 Report - Funding and merger and acquisition activity for the smart grid sector." *www.mercomcapital.com*. Mercom Capital Group, LLC, 2011. Web. <http://www.mercomcapital.com/reports/Q22011/MercomSmartGridQ22011Report.pdf>.

35. Sibley, Lisa. "Smart Grid may come to Moffet Park." *The Business Journal's Digital Network*. Silicon Valley / San Jose Business Journal, March 11, 2011. Web. August 28 2011.

<http://www.bizjournals.com/sanjose/news/2011/03/11/smart-grid-may-come-to-moffett-park.html>.

36. Kiesling, Lynne. "Dynamic Pricing is Smart Grid's Secret Sauce." *www.smartgridnews.com*. 2010 SmartGridNews, May 13, 2008. Web. August 28 2011. <http://www.smartgridnews.com/artman/publish/article_441.html>.

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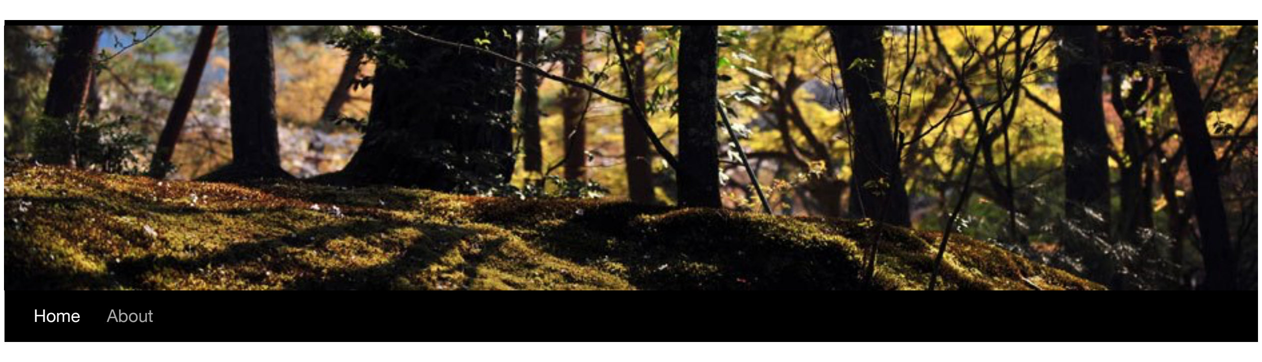

Design Case for Building a Smart City

Posted on February 28, 2016 by colorearthgreen

How we define a smart city today is different for most of us. In this era of smart gadgets and ubiquitous connectivity, most of the times we describe it as information communication technology driven development which will be enhanced by cloud connected devices. Building intelligent interactive environments with embedded systems into physical objects, infrastructures, and the surroundings in which we live, travel, and work.

Artificial intelligence and Internet of Things is the cutting edge requirement in every product development today but if we see the big picture, a Smart City should be really described as a self sustaining city which is not only well connected with public transit, smart buildings with energy management devices but zero waste, uses renewable energy resources, stimulating economic growth, reducing poverty. In nut shell a city with a smaller carbon footprint.

Building Components of a Smart City

There are various indicators used to rank a smart city. These indicators as presented by various research groups that measure the city include built environment, mobility, government policies, economic development, education, well being and life style.

We need to remember the real thing is using our resources efficiently – reduce, reuse and recycle items used in our daily life. Purposefully using waste materials for building and manufacturing products. Some examples are use of dual purpose elements like a building integrated photovoltaic glazing which provides renewable energy onsite and reduces material usage, using recycled materials in manufacturing, including the use of water efficiently or passive designing of city infrastructure for less need for air conditioning in summer and winter seasons and a well connected and easily accessible public transit to reduce traffic congestion and reducing GHG emissions. Reducing waste would be a key to reducing landfills in our city to reduce contamination of our water resources and vegetation. Similarly, for growing local agriculture buying more locally grown produce encourages local farmers and builds local economy. As developers and designers we need to think about these best practices when we develop a smart city infrastructure. Well connected urban infrastructure and suburbs designed efficiently which use less energy.

A smart city means a hi-tech intelligent city which can sustain population growth and provide job security for all community members. Transitioning to an automated city is a dream to move ourselves to a space-age era but carefully thinking of an economically well integrated city development plan will make it successful in years to come. Urbanization and well organized suburbs for community development increases the well being of the inhabitants.

A smart city is prepared to restore itself after any disaster. How well a city is digitally able to restore its connectedness, mobility, energy and water services is the most important factor of ranking a city to be an intelligent city. There is a need to provide education to the public to diminish any aspects of creating a digital divide which is an economic and social inequality with regard to access to, use of, or impact of information and communication technologies. We are looking in future for an intelligent environment where every device is seamlessly connected providing user friendly/ accessible experience for all classes.

The more enriched and connected the community the more growth we see. Active community neighborhoods with cultural bonding plays an important role in a city development. A city which makes everything accessible at your fingertips, is well connected, energy efficient and with flourishing community is why we need to build more smart city's in future.

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Social Platforms – A New Way towards Energy Efficiency

Posted on February 14, 2012 by colorearthgreen

Author: Anuradha Munshi

Social platforms are ushering in a new way to promote energy efficiency. By using behavioral principles of goal setting, social comparison (comparing your energy efficiency with your neighbors), customized and personalized reporting, rewarding you for being energy efficient, blogging, trending, letting you share your success stories while following others' and other incentives, these platforms are defining new inroads towards consumer engagement for achieving energy efficiency.

Leading the way in this venture are companies like Opower, Efficiency 2.0, Simple Energy, Tendril Inc to name a few. While these companies all have different approaches towards creating a social network for energy, yet their goal is the same: capture an audience that can be motivated to being much more energy efficient through online social interactions and engagements. Following the success of social networks like Facebook, these new ventures are aimed at creating the new social platform for energy. Some of their noteworthy aspects are captured below.

Opower – Opower today defines itself as a customer engagement platform for the utility industry. Its online tools are available through the 60 or more Utility providers that it has partnered with and consumers can benefit from them. Opower generates customized Home Energy Reports which are personalized; these give the user an analysis of their energy usage, and provide comparisons with their neighbors' energy efficiency. Opower also has an online Marketplace that brings together utilities, retailers, manufacturers in the context of reward programs for utility customers. This marketplace allows users to take benefit of personalized rebates and coupons from their utilities which can be redeemed at retail stores, and helps increase customer-participation in the energy efficiency cycle. Their research shows that sharing individualized energy consumption analysis with users results in a nearly 80% increase in participation.

On the other hand Efficiency 2.0 has a unique Personal Energy Efficiency Rewards Program (PEER) which uses sophisticated evaluation criteria and makes use of four key behavioral insights to increase customer participation:

- Personalized Recommendations – As a recommendation engine that analyses and ranks actions and purchases based on factors like popularity and payback periods, PEER uses this data to send its customers personalized energy recommendations and savings estimates without any surveys or audits.
- Goal Tracking – It sends periodic emails to customers that track their progress in lowering their energy bills and also points out where they are using maximum energy.
- Social Context and Competition – Customers are able to see how energy savings compare to their neighbors and they can also compete for prizes.
- Rewarding Savings – PEER issues reward points to customers based on how much energy they save. These points can be redeemed for discounts at national and local stores.

Yet other companies like Tendril focus on creating the cloud platform, automation control of smart in-home energy devices, and energy social applications that become the backbone for communication for energy based social media. Based on research grounded in behavioral science, Tendril Energize allows energy service providers to meet customers where they are—through home energy reports, a web application, or mobile applications for the iPhone and Android—to spark an ongoing and evolving dialogue with today's energy consumer.

The power of partnerships – Opower has recently announced a partnership with Facebook in creating a social energy application. Users will be able to compare their energy usage with friends, enter energy saving competitions and share tips on how to save energy. Commonwealth Edison (ComED), the city of Palo Alto (CA) and Glendale Water and Power (GWP) are the first U.S. utilities who will participate in this social app allowing their customers to automatically import their energy data into this app. Similarly Simple Energy and Tendril have partnered together in San Diego Gas and Electric (SDG&E) biggest energy saver campaign in CA and results indicate that on an average consumers were able to save 20% of their energy savings with this program. Tendril also has created partnerships for Electric Vehicles, leveraging their technology into other energy specific domains while still providing a social media interface for the consumer.

Government and the social energy platform – The Department of Energy is also moving towards social media platforms to educate users about energy efficiency. DOE's website explains various initiatives that it is taking to orient itself around these ideas. Similarly, Lawrence Berkeley National Lab's Home Energy Pros is yet another energy-based social media engagement platform which has a large number of registered participants already.

While it remains to be seen how these companies carry forward and translate their ideas into success, it is clear that there is now a new way of using social media platforms for promoting energy efficiency that is slowly and steadily gaining acceptance in the community. By forming strategic partnerships with utilities, with market leaders or with each other, and backed by behavioral research on user acceptance criteria of a platform, these companies are paving a new way of promoting energy efficiency efficiently among the masses.

Posted in Uncategorized | Tagged Energy, Social | Leave a comment

BIPV – Building the Way to a Renewable Future

Posted on May 23, 2011 by colorearthgreen

Author: Anuradha Munshi

Building Integrated Photovoltaics, also known as BIPV, are photovoltaic materials that can be directly embedded inside conventional parts of the building envelope, for example in a building's roof, skylights, window overhangs and exterior wall façades. Once these photovoltaic materials are embedded, they can serve as primary or secondary sources of power to the building as they make use of the sun's energy.

BIPV today offers a very viable alternative to traditional building materials as this technology is increasingly being used in the construction of new buildings. Existing buildings can be retrofitted with BIPV as well. To the homeowner or the building investor who wants to go solar on the entire building, use clean energy and save on monthly electric bills, this is a very attractive option.

But there is another reason for its popularity: low initial cost. Other than simultaneously serving as the building envelope material and a power generator, a big advantage of using integrated photovoltaic materials in place of traditional materials in a building is that it reduces the initial cost by lowering the amount spent on materials and labor than would have otherwise been utilized with conventional building processes. This single factor alone makes BIPVs one of the fastest growing segments of the PV industry today.

BIPV Design Considerations

A BIPV system's design has to be carefully planned and must take into account various factors like the building's intended use, electrical loads, its location and orientation, the relevant building and safety codes, the utility provider's own costs and issues and PV efficiency among other things. As an example, providing adequate ventilation is important during the BIPV process for maintaining the PV conversion efficiencies. When embedded in a building, PV efficiencies usually get reduced at elevated operating temperatures. To prevent or offset this from happening, the design should allow for appropriate ventilation behind the modules.

Another consideration when designing BIPV is to compare the peak building loads to the peak power outputs of the PV array. The analysis may reveal that an alternative backup should be integrated into the system to offset the most expensive power demand periods for the building. As another option to optimize system efficiency, a designer may also choose to capture and reuse the solar thermal resource that is developed through the heating of the modules. This can be a very attractive option specially when installing BIPV in cold places.

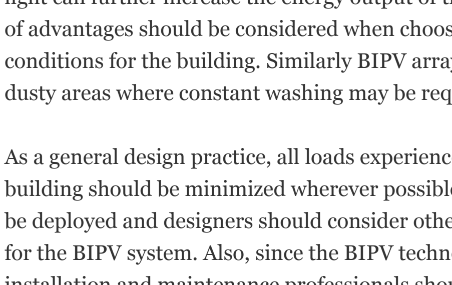
Another important design consideration is planning the orientation of the embedded PV array. Different orientations can have significant impact on the annual energy output of the system. Tilted arrays in a BIPV system usually generate 50% – 70% more electricity than a vertical façade would do. Similarly, shading effects must be considered for the design. For example, the system should be completely un-shaded for at least 3 hours on either side of the solar noon. The impact of shading is directly related to the output of the BIPV array.

Designers also need to carefully consider the impacts of the local environment and climate to the PV array output. For example, cold and clear days will increase the energy output of the array, while hot and overcast days can reduce the output. The BIPV arrays must be designed for potential snow and wind-loading conditions. As an example, proper tilt angles can help shed the snow faster. At the same time, surfaces like snow that reflect light can further increase the energy output of the array. This implies that a judicious mix of advantages should be considered when choosing the tilt angle keeping in mind local conditions for the building. Similarly BIPV arrays should also be designed for dry and dusty areas where constant washing may be required to control the efficiency losses.

As a general design practice, all loads experienced by the BIPV system in the building should be minimized wherever possible. Energy efficient motors should be deployed and designers should consider other such peak reduction strategies for the BIPV system. Also, since the BIPV technology is relatively new, all design, installation and maintenance professionals should be properly trained, licensed and experienced in PV systems work.

Aesthetically, BIPV systems can be designed to blend with traditional building materials and designs, or they can be used to create unconventional futuristic looks, based on the choice of the building owner. Semi-transparent arrays of spaced crystalline cells can provide diffuse and interior natural lighting.

BIPV Research and Public Awareness



Solar Decathlon 2009 Home by Team Germany

The U.S. Government believes that PV should be a widely accepted technology in the 21st century with increasing number of solar powered homes and business that support and showcase the use of PV technology. The use of BIPV is supported by the Government in two distinct ways, i.e. by research and by raising awareness. BIPV technology is actively researched and improvised in many organizations like the National Renewable Energy Laboratory (NREL) where BIPV researchers investigate how to improve system reliability and reduce costs and utility transmission losses while further improving the market acceptance of this technology.

At the same time, the U.S. Department of Energy Solar Decathlon organizes the Solar Decathlon annual event, where 20 collegiate teams throughout the U.S. are challenged to design, build and operate solar- power homes that are cost-efficient and energy efficient while being attractive to the market. These teams spend about 2 years and design solar-powered homes that showcase technologies like BIPV to the world during these annual events. The decathlons are essential for not only motivating the emerging breed of students and engineers to think more about solar powered homes, but also in raising general public awareness, as people come, see and learn about these houses during these competitions.

BIPV as a technology is a very cost effective way towards building energy efficient homes and business establishments in our communities and societies. With properly guided design, ongoing research and increasing public awareness, BIPV can become a very effective medium to showcase solar technology and to increase its widespread use in the future.

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Hello world!

Posted on April 14, 2011 by colorearthgreen

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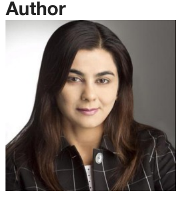

Anuradha Munshi

Carbon Footprint of Electric Vehicles

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1. INTRODUCTION

The age of the electric car is finally upon us. The early, exploratory efforts by automakers and users in the late 1990s and the successful introduction of gas-electric hybrids in the last 10 years have shown that consumers both in America and Worldwide are ready and willing to use this "new" form of transportation. When the automobile was first introduced in the 1890s, there were no roads or infrastructure. But things are different, there is a massive effort underway to expand the amount of charging stations available to electric car users both in the US, but worldwide, which should quickly guarantee its place as a significant part of the transportation architecture.

But is there a dark side to the electric car? Can electric cars be manufactured and disposed of with less carbon emissions and pollution than current conventional vehicles? Because they will operate on electricity that could come from coal burning as well as hydroelectric plants, will they really operate cleaner than gasoline cars? What about their operations worldwide? Is the infrastructure being developed and will they operate as cleanly in the rest of the world? Finally, is the electric car best the transportation direction to pursue with our limited energy and fragile environmental resources? This paper will attempt to address these and other issues related to the introduction and use of the electric car.

The thesis statement for our research is that *"The introduction of electric ears will reduce carbon emissions in the US and worldwide, and will also reduce the degradation of earth resources.*

RESEARCH

2. <u>Vehicle Manufacturing and Disposal Effects (Anuradha Munshi)</u>

EV Manufacture and Disposal Impacts on WASSEEM and Climate (CO2 Emissions)

This section presents an analysis of the CO2 carbon emissions and impacts on WASSEEM for an Electric Vehicle during the Manufacturing and Disposal stages of its life cycle. Comparisons are made wherever possible to similar stages of a Conventional car's life cycle. Finally the section presents some techniques used and recommendations for car manufacturers to further reduce GHG emissions during these stages of an Electric Vehicle (EV).

With electric cars being introduced into the market, it becomes essential to understand and analyze environmental costs associated with their manufacture and recycling processes. Typically for Battery Electric Vehicles (BEV) emphasis is often placed on tailpipe emission reductions and energy savings during operational phase. However not much data is available or understood regarding GHG emissions or environmental impacts during the manufacturing and disposal stage of the EV including the battery. In this section we show that there are various processes within the manufacture and disposal phases which can significantly contribute to the overall environmental impact of an EV during its lifetime.

2.1 EV Life Cycle: Pre-Manufacture impact

We begin by classifying various stages of an Electric Vehicle's life cycle. Like a conventional vehicle, typical stages of an Electric Vehicle's life cycle include pre-manufacture, manufacture, operations and post-operation or recycling. Figure AM 1 shows the life cycle stages of an EV versus a Conventional Car and highlights the similarities and differences between the two.

Unlike a conventional car, the fuel source of an EV is electricity available via its battery. However, in order to produce electricity various processes are typically involved and must be considered for environmental impacts. For example, if conventional fuels are used for electricity, then the EV lifecycle actually begins with fuel extraction (coal, natural-gas, uranium or crude-oil), fuel transportation, electricity generation and distribution, leading to manufacturing plant operations for producing EV. Also unlike the conventional car, the production and disposal of the electric battery is a unique process for the EV. All of these processes when taken in isolation become individual contributors to CO2 emissions and environmental impacts of an EV.

An extensive study report titled "Total Energy Assessment of Electric and Conventional Vehicle: An Energy and Environmental Analysis" by ANL (Argonne National Lab) in collaboration with NREL (National Renewable Energy Lab) and PNNL (Pacific Northwest National Lab) for the U.S. Department of Energy (Cuenca, Formento, Gaines, et al) analyzes CO2 emissions during the pre manufacturing and manufacturing phases of an EV.

The report analyzes airborne emissions of CO2, methane (CH4), sulphur oxide (SOx), nitrogen oxide (NOx), carbon monoxide (CO), volatile organic compounds (VOC) and lead (Pb) for manufacturing, disposal and other stages of an EV under various conditions and across different geographical areas in the U.S.

According to the studies carried out in this report, 22% of a typical EV's CO2 emissions result from their non-operational phase, which is from pre-manufacture and manufacture. 11% of CO2 emissions are from fuel extraction and production, 7% are from manufacturing, 4% are from ancillary production. A surprising result of this study is that for an EV, the contribution to CO2 emissions from power plants is almost double than that of conventional plants. This is in part due to the electric battery production phase but also because of the materials used for EV design.

Another paper titled "On the road in 2020: A life cycle analysis of new automobile technologies" from MIT, MSL labs (Weiss, Haywood, Drake, et al**)**, reports that non-operational phases of a typical vehicle may account for nearly 25% of total CO2 emissions. Figure AM 2 further illustrates this. Other sources like (Berners-Lee, and Clark) also suggest that a considerable amount of CO2 emissions occur prior to the operational phase of an EV (material extraction for example) and should be taken into account when deciding to trade in an older car for an EV.

2.2 EV Manufacture impact on the environment

The EV manufacture process impact comes from the materials chosen to design the body of the EV as well as the manufacturing of the Electric Battery. Figure AM3 shows percentage of materials used in an automobile. According to various sources like (automobile 1), (automobile 2)**,** (malnati)**,** the weight of an EV is typically dominated by its electric battery and electric propulsion system which makes up for nearly 40% of the EV weight. In order to mitigate this impact, EV designers typically choose Aluminum (Al) as the skeleton framework for an EV as Al is lightweight and strong as compared to Steel, the usual material choice for conventional cars.

However, many studies have found that CO2 emissions resulting from the material extraction and usage of Al for EV are typically greater than emissions from steel for conventional vehicles. A paper titled "Life Cycle Cost Analysis: Aluminum vs. Steel in passenger cars" (Ungureanu, Das, and Jawahir) that compares the emissions from usage of Aluminum vs. steel across various stages of car manufacturing, finds that Al results in higher emissions in the extraction phase, although the emissions tend to reduce when Al is used in the operational stage. Figures AM 4 and AM 5 provide a summary of data from this paper. For example figure AM 4 compares CO2 emissions in the BIW process for EV manufacturing using recycled Al vs. recycled Steel, while figure AM 5 extends this for an LCA analysis comparing Aluminum and Steel.

The other two tables in Figure AM 6 and Figure AM 7 list observed airborne emission values based on various materials that are used for EV and conventional car manufacturing. This data in these figures comes from (Cuenca, Formento, Gaines, et al)**.**

According to various sources EV power plants could also be negatively impacting the environment by polluting the ground and surface water surrounding these plants if metallic residues involved in EV production are leaked out from these sites.

EV manufacturing companies such as Nissan typically have their manufacturing units outside of the US, in Japan. Similarly Tesla imports car parts from Europe. This increases the pre-manufacturing and manufacturing transportation environmental impact in bringing in car parts and other materials for assembly and contributes to overall CO2 emissions.

Car manufacture plants, especially sophisticated ones for EV, also typically consume a lot of electricity in deploying automation tools for assembling car parts among other things. A choice to use conventional vs. renewable energy for electricity plays an important role in determining the impact of CO2 emissions by these plants. For example manufacturing plants should look at using alternative sources of electricity generation at site like solar, fuel cell or wind to bring down CO2 emission levels.

Major automakers like Ford, GM and Toyota every year need to submit sustainability reports which indicate their CO2 emission levels during car manufacturing. According to some sources like (Brown)**,** these reports sometimes do not actually have all the elements and data about the actual carbon emissions produced (Ford). For example, information is only given on the energy used at the plants, but nothing is mentioned about the transportation of materials, parts and travel by company employees: factors which contribute to carbon dioxide emissions and other environmental impacts.

On the other hand, major automakers like GM are taking steps to create sustainable manufacturing plants. As shown figure AM 8, GM (Dreher, Lawler and Stewart) has developed a sustainable metric based system to monitor and evaluate CO2 emissions and environmental impacts. Metrics include measuring pollutants in underground water, CO2 emissions per unit, footprint of business travel and so on. Such measures will go a long way in reducing manufacturing emissions.

2.3 EV Post Operation impacts to the environment

The disposal of an EV typically consists of various stages like dismantling, shredding and metallic separation. These stages are necessary to incrementally scrap and remove potential pollutants to the environment. Figure AM 9 shows a typical car recycling process.

Metals account for nearly 76% of a conventional car by weight in its end-of-life stage, where Al is around 8% (Waste Online) whereas for EV lighter non-ferrous elements like Aluminum will increase as EVs get introduced and reach end-of-life. 98% of metals are recoverable and recyclable. Aluminum on subsequent recycles can lose its degree of CO2 emissivity as shown in (Ungureanu, Das, and Jawahir)**.** Plastics are on the rise in cars (8% to 11%) (Waste Online) and there is a concern that PVC based materials have difficulty in getting recycled, raise emission levels and so automakers should look at PVC alternatives. This study discusses various recycle options for car tires, glass and other components and examines possible environmental effects.

Studies like (Kanari, Pineau, Shallari) further describe recycling strategies. They point out that automobile parts go to landfills with negative environmental impacts and suggest that Governments should actively promote laws that require minimum landfill disposals and maximum recycling of vehicles.

2.4 Battery manufacture and disposal impact on the environment

An EV's environmental impact of the production and disposal of its battery depends on the metal composition of the battery. There are primarily 6 types of batteries for EVs. These are lead-acid, nickel-metal hydride, nickel cadmium, lithium-ion, zinc-air or flywheels. Of these, EVs today use Lithium-Ion batteries because it is the lightest amongst all, has high power and energy density, is safe, long-lasting, affordable, and does not easily lose charge.

Studies reveal that lead-acid based batteries have the worst environmental impact while the lithium-ion batteries cause minimal impact. For example, a study titled "Contribution of Li-Ion batteries to the environmental impact of Electric Vehicles" (Notter, Gauch, and Widmer) suggests that production of a Li-ion battery plays a minor role when calculating EV CO2 emissions, to just around 2.3%. This can be lowered by using materials like scrapped aluminum for electrolytes instead of standard copper. Other reports like (Bacher**)** suggest that Li-ion has a minor role yet places a burden on the environment when pre-operational battery related environmental impacts are considered.

For example, (Bacher) indicates that mining of the material used for EV battery can lead to harmful levels of metals ending up in ground-water, surface water and air. Similarly Li is further processed by refining through electrolysis which sends harmful pollutants in the air. Also mass production of EV batteries can result in negative environmental impacts, like reduced fishery near mining sites, decreasing air quality and higher energy costs.

EV Battery reusing and recycling process should be followed at the end of the battery's life cycle (usually around 10 years) even though some batteries like Nissan's for the Leaf will retain 80% of their energy. Studies suggest that some EV car batteries may release metals as pollutants when being scrapped, so the metal should always be recovered before the battery's disposal. Other end uses include Li ion batteries for storing grid energy. Toxco is one of the few companies in the world which recycles Li ion batteries and transforms them into commodities like Cobalt, Copper, Nickel and Lithium Carbonate for resale.

2.5 Green Initiatives by Auto Manufacturers

Manufacturers are employing novel methods to reduce GHG emissions from their manufacturing plants. For example as explained in (Voelker 1), Toyota has introduced two new species of flowers specifically to help reduce the environmental impacts of manufacturing Prius at its Tsutsumi plant in Japan. One is a cherry sage plant derivative with leaves that absorb Nitrogen Oxide. The other is a gardenia derivative that releases water vapor into the air which reduces temperature around the facility cutting the need of air conditioning inside the building.

Other elements in Toyota's facility include rooftop solar panels to generate electricity and exterior paints that absorb both nitrous oxides and sulphur oxides from the air. Some of the other energy efficient features are use of motion sensing switches which turn off lights in unoccupied bathrooms and reflective daylight tubes that provide ample daylight in rooms replacing electric lights. Toyota has planted 5000 trees last year to offset factory's carbon dioxide emissions.

Other automakers like Ford are working on using renewable materials to reduce the use of metal, plastic and glass in the car body. Ford reinforces plastic storage bins and door panels with wheat straw as per (Voelker 2). Other experiments are going on using flax and the family of prairie grasses which one day could displace the use of glass fiber or mineral reinforcements.

The use of green materials would not only reduce the carbon footprint of vehicle manufacturing but would also reduce overall vehicle weight and increasing energy efficiency.

Ford uses leftover steel from pick-up truck body for its new Ford Explorer 2011 model (Voelker 3). They have estimated that this process will save 119 tons of new steel a year reducing CO_2 by the equivalent of 350,000miles in a midsize car. Another is use of soy based rubber in other parts of car. Ford says it uses 25-30 million pounds of plastic waste diverted from landfills and these recycling efforts have saved them up to $ 5 million.

On the other hand General Motors uses old jeans and used carpet for the interiors of its vehicle. The Subaru manufacturing plant in Indiana sends no waste to landfills. The facility eliminates or recycles all its scrap.

3. U.S.Electric Car Operations and Infrastructure (Greg Pisanich)

3.1 Energy Use

Running purely off batteries, electric vehicles have zero emissions from operations (do not emit tailpipe emissions). But when they are charging, do they actually emit less carbon dioxide than conventional vehicles? The answer to this question depends on the vehicle design, how it is utilized, and from where the power is sourced. Numerous research studies have been performed to examine this question. Notable examples include (Moyer 54-55), (Dutton).

A recent study by the National Resource Council found that, when compared with refueling a conventional automobile, an electric car will emit less CO^2 assuming that the power used is similar to an average U.S. power source mixture (Dutton) In their study, an electric car operating 60 miles a day will result in 32 lbs of Carbon emissions compared with 47 lbs for a standard automobile.

However this result can differ when you consider the location within the country where the vehicle is being charged. Scientific American reported on a more exhaustive study performed by the Department of Energy (Moyer 54-55) comparing all electric vehicles to plug in hybrids. In this study, the country was split into 13 regions related to their mix of energy, coal, natural gas, nuclear, and renewables (see figure GP1). They found that in regions where the power mix is relatively clean, CO^2 emissions from Electrics can be as much as 40% less, whereas in regions primarily powered by coal, the CO^2 emitted into the atmosphere can be the same or more than a hybrid vehicle. The National Resource Council Study provided similar results: as little as 18 lbs of CO^2 emissions for a 60 mile commute charge in relatively clean New York, vs. 47lbs of CO^2 in Coal-powered Denver (equivalent to a gas powered auto) (Dutton).

Two considerations of these studies: The Department of Energy researchers considered the nuclear and renewable energy sources as always on, being entirely used for used for normal charging and not available for green energy charging (the dirtiest power was used first). Also surprisingly, neither of these studies considered the often overlooked non-CO^2 costs of energy generation, for example, water waste, decommissioning nuclear plants, or the economic costs of damming rivers.

The time of day that an electric car is chargedr can also make a difference in the emissions. The conventional wisdom is that charging your electric vehicle at night should reduce the demand for energy during the peak hours of the day. Charging at night will help recover the wasted energy that plants produce but can't always use (Dutton). Charging will be addressed in more detail in a later section of the paper.

3.2 Maintenance Costs

Electric and conventional/hybrid cars share many of the same systems. These include the chassis, interior, glass, instrumentation, brake fluid, wheels and tires. Conventional wisdom would assume that these systems will have about the same life as current automobiles. Recycling programs and efforts are already in place to mark and recycle these auto parts.

The major difference will be in the consumables associated with the motor/engine. Without a gasoline engine, there are no oil changes, and no radiators to service. An electric car will have batteries and depend on them for all its motive power. Pure electric vehicles such as the Nissan Leaf and the Tesla will eventually require their batteries to be changed out so that a commuter can retain maximum power and range. However, because of the lithium batteries will retain most of their storage capacity after even 10 years (Team Planet Green); companies are already planning to repurpose them for use in stationary energy storage and load balancing in solar, wind farms, hospitals, and server farms applications. Nissan expects demand in Japan to be so great by 2020 that it would need 50,000 EV batteries to meet) (Sqiatriglia). Repurposing and recycling will help avoid reduce the amount of mining operations needed to support these vehicles.

3.3 Infrastructure Environmental Costs

In addition to the operating costs, what also must be considered is the environmental tradeoffs of building out the charging infrastructure needed to service the vehicles, and the costs of any upgrades to the power Grid required to supply the additional energy.

A conventional model for an electric vehicle is for them to be charged at home, operated for a 60 mile round trip to work or shopping, and then back home to be recharged for the same usage the next day. The time that it takes to charge a vehicle depends on the power available. An electric car like the Leaf, plugged into a standard home110V wall plug, will fully recharge in 8-12 hours (Pacific Gas & Electric 2). This is called level 1 charging. It can recharge at half that time using a 220V plug (Level 2, the same as your home Dryer) in 4-8 hours (Pacific Gas & Electric 2). Providing a 220V outlet will require additional wiring and a special charger to be installed in your home and will increase the current draw on your home (Pacific Gas & Electric 3). The cost is ~$2000 + installation; some of the Auto companies are providing these as part of the auto purchase (Pacific Gas & Electric 3). More specialized cars like the Tesla are capable of accepting a 440V charge, bringing it to 80% capacity in as little as 15 minutes, but these level 4 chargers come with a $30K price tag and may be a concern to Utilities (Woody). Although no figures were available, it is assumed that even a simple 220V install will require a significant amount of copper and electronics to be sourced and developed.

Note that without the special chargers, recharging a vehicle for 20 hours (@ 110V) will necessarily put this task a time that may occur in the evening when power for air conditioning, heating, or other power is typically used: you may be limited in your charging time until your area is upgraded (Pacific Gas & Electric). Long charge times may require other less clean power to be brought on line to service this need (Dutton). Also in early adopter areas such as the Bay area, adding 3-4 electric cars into a local neighborhood may require the local power company to upgrade the distribution equipment, wires, and transformers (Dutton, PG&E 3) which will require metal resources and eventual recycling of these materials.

A second conventional model is for an electric car to be driven to work or shopping, recharged while at that location using a charging station, and driven back home to be topped off. This will require a massive build out of charging resources, by private (Star Ledger News Desk) (Addison), State (Alspach), and municipal concerns (Associated Press), which is well underway. Companies such as GE, Coulombtech, and SolSource Energy are supplying this equipment to cities from San Jose (Woody 2), to South Carolina (Associated Press). And not only forward-thinking, leading-edge retailers such as "Whole Foods (Jensen) are working to install charging stations for their customers, but also conventional retailers such as Wal-Mart (Star Ledger News Desk) and McDonalds (Rye). We can also expect to see many of the 117,000 gas stations installing this capability (Knightstep).
An innovative model being planned in Boston is to install charging stations in parking lots created on urban brownfields (O'Brien). On one hand, these charging stations will also require metals and electronics that will be drawn away from the earth. Charging at mid day may also be an issue at some times of the year when and where heating or cooling use is in demand. On the other hand, with the use of smart grid (LaMonica), (Leeds), and Vehicle to Grid technologies (Wikipedia) a utility's use of an unneeded 5 mile portion of an electric car's range to provide overload power in the middle of the day to be replaced in the evening, should reduce the requirement to expand the grid.

A third model of use is for cross-State, and very soon, cross country driving. Tesla is already working with companies to install fast charging station along 101 and Interstate 5 between San Francisco and Los Angeles (O'Dell). Nissan's Leaf will provide the location of the closest recharging area on its mapping software (Padgett) and certainly others will follow. An additional consideration is that if electric vehicles are driven across the country, the average CO^2 they produce may revert back to the average purported reported earlier.

4. Operational Effects Worldwide (Ayako Hirokawa)

Studies show that CO2 emission from transportation vehicles comprises most of the total worldwide CO2 emission (Rogers). As figure AH1 shows, 23% of CO2 emissions that comes from fuel combustion worldwide is from transportation vehicles (45% Energy, 19% Manufacturing industries and construction, 12% Other Sectors). The total amount of CO2 emissions worldwide is about 30 million tons, which means that CO2 emissions from transportation vehicles worldwide amount to 6.9 million tons. Figure AH2, "Shares of Transport CO2 emissions 2005", shows that 42% of transportation emissions are from cars and light- duty vehicles, and 24% of the emissions are from medium and large trucks, so we will be focusing on these.

4.1 Carbon emissions from cars: US compared to other countries

This compares the US to other countries in terms of road emissions and is from the international transport Forum. Figure AH3 shows that the carbon emissions from the U.S. due to transportation vehicles on the roads are huge. The total quantity is much greater than that of the rest of the countries. Asian countries especially China and Japan follow the U.S. in terms of carbon emissions (Quick).

When it comes to Road CO2 emission per driver, the average CO2 emission is 4.009 tones (5.16 x 777/ 1000) in the U.S. whereas the average in Japan is 0.787 tones (1.76 x 447/1000) and the one in China is 0.005 (0.3 x 17/1000) (Nationmaster). The introduction of Electric Vehicle can be more effective in countries where Road CO2 emission per driver is high.

4.2 Provision of countries

According to IDC Energy Insights, 540,000 plug-in Electric vehicles will be sold globally by 2012. Furthermore, more than 2.7 million vehicles will be on the roads within five years, including 885.000 electric cars in North America, and more than 780,000 in Europe by 2015. The study says, however, that the electric grid will not be ready for this surge. The problem of the utilities will also need to be addressed--specifically the control of how and when the vehicles are charged.

4.3 EU

Portugal was one of the first countries in the world to adopt a countrywide electric mobility policy. Portugal already has 43% of its electricity provided by renewable energy and they are finding ways to use energy that is wasted at night currently. The government of Portugal has also launched a national Program for EV. The program is multi-operator and multi-retailer model. Portugal has an integrated policy for electric mobility and a national charging network. By 2011, 1300 normal, and 50 fast-charging stations will be implemented at shopping centers, car parks, petrol stations and hotels in the main 25 cities of the country. In addition, the Nissan Leaf will be available in Portugal in December 2010 (Wikipedia 1).

Solar Support

Portugal's solar power sector supported by big government incentives, however; unlike Spain and Germany, which are looking to trim support for solar projects, Lisbon has no plans to cut subsides.

Major provision

Here are the major provisions for EV in Portugal towards support for solar projects (Fineren), (Innovation Europe Staff).

(1) EVs are fully exempt from vehicle tax purchases and the annual Circulation Tax.
(2) Personal Income Tax provides an allowance of 803 Euros upon the purchase of EVs.
(3) EVs are fully exempt from the 5%-10% company car tax rates, which are part of the Corporation Income Tax.

(4) The Law provides for an increase in the depreciation costs related to the purchase of EVs for the purpose of corporation income taxes.
(5) The first 5,000 EVs to be sold in Portugal will receive a 5,000€ incentive fund, and the Cash-for-Clunkers program grants an additional 1,500€ fund if an internal combustion engine vehicle built before 2000 is delivered when acquiring the new EV.
(6) The Portuguese State has also committed to play a pedagogic role and has declared that EVs will have a 20% share of the annual renewal of public car fleets, starting in 2011.

4.4 Asia

According to the Pike Research article, total sales of plug- in hybrid and all-electric vehicle will be over 1.4 million in Asia Pacific by 2015. There are programs to promote the awareness of electric Vehicles, which include the tax incentives, regulation and standardization, public education, etc (EV Future). The local and national government have been taken attention to the potential for reducing carbon emissions by electrical transportation emissions to climate change. Especially, China will be the largest market for Plug in Electric Vehicle in Asia Pacific within five years (Bradsher). The majority PEV in China will be "battery electric vehicles" which is a type of Electric Vehicle that uses chemical energy stores in rechargeable battery packs. In contrast, a plug-hybrid electric vehicle which is hybrid vehicle with rechargeable batteries can be restored to full charge by connecting a plug to an external electric power source, will be largest categories in Japan.

Government of India has announced an incentive for Electric Vehicles in India.
Each manufacturer of Electric Vehicles will receive financial incentives for every EV sold in India. The incentives are planned for up to 20% of the ex-factory prices of the vehicles, subject to a maximum limit. The incentive will be Rs.4, 000 for low-speed electric two wheelers, Rs.5, 000 for high-speed electric two wheelers and Rs.1 lace for an electric car.

4.5 REVA

REVA Electric Car Company Private Ltd in Bangalore, India, is a company established in 1994 that commercialized the first REVA car in June 2001 (Lakshman). This two-passenger city car is priced at about $12,000 and the company has been selling it in India and Europe since 2001. It was first reserved for the Indian market, but it is now selling in several European countries such as UK, Greece, Belgium, Norway, Iceland and Spain.(Wikipedia 2)

4.6 South America

Brazil has been announced that Solar Powered Charging Stations for Electric Vehicle build in a town near Reo de Janeiro because that area has many electric motorcycle and bikes in the country. Interesting thing about charging station is that it can get solar power wherever the sun's shining, but it could work even when it is dark. According Brazilian industrialist, it is planned to to build a $ 1 billion electric Vehicle manufacturing plant in near Rio de Janeiro. Brazilian company, which has oil, electricity and logistics, has said they wants to work with Japanese and European companies to build Electric Vehicles in Brazil.

In these last three years, "Fiat Palio Weekend" Electric car has been development(Admin). Fiat says Palio's maximum speed will be 100km/hr and its price will be approximately US $70,000. The battery of the car is completely recyclable.

5. Transportation Alternatives to the Electric Car (Matthew Reeves)

Automobiles currently running on fossil fuels emit large amounts of CO^2 from the burning of oil in their engines. The electric car and its manufacturers publicize the fact that electric vehicles significantly reduce carbon emissions when compared to conventional cars. The problem is that there are many wasteful, carbon emitting support systems that go with that vehicle, be it electric or gasoline powered. These changes have large impacts on the carbon footprint of many daily activities and how most Americans live their lives, including home energy use, transportation options and decentralized job locations.

5.1 Growth of Suburbs

The growth of suburbs in metropolitan areas saw a sharp rise in the post-World War II years due to increased manufacturing capacity and the introduction of the Interstate Highway System and subsequent local freeway systems. An example by Wiewel in Suburban Sprawl is that the demand for cheaper land drew companies and citizens away from the central cities and towards cheaper suburbs, which was then facilitated by the introduction of highways to those suburbs. Suburbs were originally centered around the downtowns of cities, but soon new suburbs grew along the fringes of urban areas, giving rise to the distinction "inner" suburb and the newer "outer suburbs". Suburbs were seen as clean and pristine, with new highways allowing for easy commuting to numerous job sites in the area. In the decades since the rise of "outer suburb", these suburban areas have grown large enough to have their own suburbs, referred to as "exurbs".

5.2 Electric Car and the Suburb

If the electric vehicle is successful and does come to replace the gasoline-powered automobile, there will still be an estimated 59% increase in auto users by 2030 according to complete streets.org. What we want to look at would be the infrastructure related to driving a single occupant vehicle, as 75.5% of Americans currently do for commuting (Forbes). In fact, in metropolitan areas, 28% of all trips are less than one mile, and of these 65% are done by car (completestreets.org). If drivers use their cars for even relatively small distances, why would a person change their driving habits if driving an electric car meant even more savings through less gas? What would be useful would be to look at is what the dependence on the automobile means and what kind of emissions savings could be accomplished in the near future, from new housing stock choices to less road construction.

5.3 New Road Construction

In the United States, thousands of lane miles of new roads are added every year. According to the American Road and Transportation Builders Association, there are

> "32, 300 lane miles of new roads constructed every year in the United States. Each new lane-mile of construction can be between 500 and 1,200 tons of CO2 emissions (pavementinteractive.org), for a total of between 16.15 and 38.76 million tons of CO2 per year, the equivalent of countries like Estonia or Switzerland, respectively. Walking requires almost no new roads/pathways in comparison as it focuses on existing infrastructure and infill development, and bike lanes are added to existing roads with mainly new paint and little maintenance. Walking and biking may require more calories to burn because of exercising or replacing clothing like shoes, but these figures are of no concern because shoes, clothing and food are all essentials that the modern American uses while driving as well, but looking at the carbon footprint of the bicycle itself is also important."

5.4 Bicycle Production

Most bicycles are currently made with steel frames and even carbon fiber, which allows for strong yet light bikes that don't waste materials. As the automobile is lessening its carbon footprint through electricity, bicycle manufacturers are looking more sustainable materials such as bamboo for future production. According to the New York Times, the number of bamboo bicycle start-ups is starting to expand across the United States. Though mass production is still far away, the carbon footprint of most bicycle frames is still relatively low as the steel frame on average weighs 3 pounds, and steel creates 2.08 pounds of CO^2 emissions per pound of steel produced for a total of 6.24 pounds CO^2. This is a very small amount in comparison to the weight of a car, which can average 2,150 pounds of steel (USGS).

5.5 Land Use and Compact Development

Land use is also a very important factor in how the electric vehicle will supposedly change carbon emissions. Of the existing housing stock, 63.2% are detached single-family homes, which hinders mobility and forces larger distances between housing and other amenities (Table 1A-1). These detached single-family homes currently total 80 million units, which is nearly 62% of all housing units in the United States. There will need to be another 57 million housing units to accommodate population growth by 2030, a 44% increase in total housing units (Gomez-Ibanez, Humphrey). This presents a large opportunity for creating new, low CO^2 emitting housing units in the coming years. These homes will more than likely be created in exurbs and other areas that limit accessibility because they will only be practical to get to by car.

An alternative to creating new suburbs and exurbs would be to orient that new housing towards walking, biking and transit. According to completestreets.org, in most metropolitan areas 50% of trips are less than three miles, which makes walking, biking and transit viable alternatives to the electric car and expands the options in housing stock to more than just detached single-family houses. This figure is also for low-density areas, which means that the amount of trips in that distance can greatly increase to make nearly all trips within the three-mile radius. It is clear that detached single-family homes require more materials, infrastructure like sewers and pipelines, energy use, and they present fewer options for transportation.

5.5 CO2 Emissions from Detached Single-Family Homes

Energy use in homes is a large source of greenhouse gas emissions in the United States, up to 17% of total emissions (US EPA). These homes are only possible by using land that surrounds metropolitan areas because it is cheap, undeveloped and is within driving distance of job centers towards the center of the metro area. By building more compact developments, savings on energy emissions can be dramatic, nearly one third the national average in the case of New York City according to a study by the International Institute for Environment and Development. The city of Boulder, Colorado, also states that energy use can be cut by nearly 60% when building compact development such as mid-rise apartment buildings compared to detached single-family home. These savings are achieved through shared walls and ceilings that capture more heat and cool air, and require less building materials. These housing units are also generally cheaper than a similarly sized detached home, which is more of an incentive for buyers and thus a reasonable alternative for consumers.

Compact development not only brings down carbon emissions by using less energy in homes but also by increased participation in public transit, walking and biking. Mixed-use developments are a type of compact development with commercial or retail uses on the bottom floor and housing on the upper floors. This creates the environment for walking and biking to be an effective alternative to purchasing a car and allows for transit use on longer trips. Transit can play an important role in facilitating the growth of compact developments and denser neighborhoods in city centers much in the same way highways helped facilitate the growth of suburbs.

5.6 The Automobile vs. Transit

Another reason an electric vehicle would detract from total carbon emission reductions is because of transit ridership. Currently, transit is a public investment that includes almost all roads, bus lines and other major transit lines. Mass transit is affected by public spending on highways and roads because roads currently receive a majority of funds, with highways receiving around 13 times the funding than mass transit according to the Sierra Club. With increased spending on transit, commuters could have better access to mass transit that gets commuters relatively long distances faster. Transit would cater toward longer distances because shorter distances, between 1 and 3 miles, would hopefully be reserved for walking and biking. Per-person and per-train carbon emissions reduction works best when ridership is high and trains are full, which would best be accomplished by building more compact development near transit stations to encourage people to walk to stations.

As an example, the Bay Area Rapid Transit system encompasses 105 miles of tracks, with an average annual carbon emission reduction of 1.85 million tons of CO^2, or around 17,600 tons of CO^2 reduced annually per mile (. Other systems with lower ridership figures don't generate the same kind of carbon savings as BART, but with increased ridership and more compact development near stations the savings could be even higher. There is a lot of room for development in and around stations, as the average density of major American cities is very low, with lots of parking lots and under utilized lots as prime locations for compact development. Considering the large number of new housing units needed to accommodate the expected growth in population and the changing needs of transit systems, this is the time and the way of making significant carbon emission reductions.

6. CONCLUSION

The introduction of Electric Vehicles should be a great solution to our transporation needs if we use our resources sustainably, are able to bring down cost of vehicles and are able to provide equal or better features than conventional cars.

On the other hand an enhanced, environmentally friendly EV mass transit system is a better long term solution.

7. REFERENCES

7.1 Electric Car Manufacturing and Disposal

Automobile, 1. "How products are made, volume 1." *www.madehow.com*. Advameg inc., 2010. Web. 5 Dec 2010. <http://www.madehow.com/Volume-1/Automobile.html>.

Automobile, 2. "How products are made, volume 5." *www.madehow.com*. Advameg inc., 2010. Web. 5 Dec 2010. <http://www.madehow.com/Volume-5/Electric-Automobile.html>.

Bacher, Diane. "Environmental Impact of Batteries used in Electric Cars." *www.ehow.com*. www.ehow.com, May 12, 2010. Web. 5 Dec 2010. <http://www.ehow.com/about_6507967_environmental-batteries-used-electric-cars.html>.

Berners-Lee, Mike, and Duncan Clark. "What's the carbon footprint of a new car." *Environment, GreenLivingBlog*. www.guardian.co.uk, 23 09 2010. Web. 5 Dec 2010. <http://www.guardian.co.uk/environment/green-living-blog/2010/sep/23/carbon-footprint-new-car>.

Brown, Susan. "Emissions." *www.ae-plus.com*. ae-plus.com, June 2007. Web. 5 Dec 2010. <http://www.ae-plus.com/key%20topics/kt-emissions-news4.htm>.

Cuenca, Roy, John Formento, Linda Gaines, et al. "Total Energy Assessment of Electric and Conventional Vehicles: An energy and environment analysis." Argonne National Lab, US. Govt., July 1997. Web. 5 Dec 2010. <http://msl1.mit.edu/pdfs/fed_docs/M98003728.pdf>

Dreher, Jonathan, Maureen Lawler, and Jereny Stewart. "General Motors - Metrics for sustainable manufacturing." *MIT Sloan Management*. May 14 2009. Web. 5 Dec 2010. <http://actionlearning.mit.edu/files/slab_files/Projects/2009/GM,%20report.pdf >.

Ford, . "Ford Report on the Business of Climate Change." *Ford*. Ford, 2005. Web. 5 Dec 2010. < http://media.ford.com/downloads/05_climate.pdf >.

Kanari, N, J-L Pineau, and S Shallari. "Total Energy Assessment of Electric and Conventional Vehicles: An energy and environment analysis." *End of Life vehicle recycling in the European Union*. TMS - The Minerals, Metals and Materials Society, August 2003. Web. 5 Dec 2010. <http://www.tms.org/pubs/journals/JOM/0308/Kanari-0308.html>.

Malnati, Peggy. "Engineering Insights: Not your father's EV." *www.compositesworld.com*. CompositesWorld, 02 05 2010. Web. 5 Dec 2010. <http://www.compositesworld.com/articles/engineering-insights-not-your-fathers-ev>.

Notter, Dominic A., Marcel Gauch, and Rolf Widmer. "Contribution of Li-Ion Batteries to the Environmental Impact of Electric Vehicles." *pubs.acs.org*. Environment Science Technology, August 9, 2010. Web. 5 Dec 2010. <http://pubs.acs.org/doi/full/10.1021/es903729a>.

Ungureanu, C.A., S. Das, and I.S. Jawahir. "Life Cycle Analysis: Aluminium vs. Steel in Passenger Cars." *www.secat.net*. TMS - The Minerals, Metals and Materials Society, 2007. Web. 5 Dec 2010. <http://www.secat.net/docs/resources/Aluminum_vs_Steel_in_Passenger_Cars07.pdf>

Voelker, John. "Toyota Creates New Flower Species To Cut CO2 From Prius Production." *www.allaboutprius.com*. www.allaboutprius.com, Nov 9, 2009. Web. 5 Dec 2010. < http://www.allaboutprius.com/blog/1038051_toyota-creates-new-flower-species-to-cut-co2-from-prius-production>.

Voelker, John. "Green Materials For Ford Flex: Renewable Canadian Wheat Straw ." *www.greencarreports.com*. www.greencarreports.com, September 13, 2010. Web. 5 Dec 2010. <http://www.greencarreports.com/blog/1049267_green-materials-for-ford-flex-renewable-canadian-wheat-straw>.

Voelker, John. "Ford Saves Scrap Steel, Stamps Explorer Parts From Pickup Leftovers." *www.greencarreports.com*. www.greencarreports.com, August 25, 2010. Web. 5 Dec 2010. <http://www.greencarreports.com/blog/1048640_ford-saves-scrap-steel-stamps-explorer-parts-from-pickup-leftovers>.

Weiss, Malcolm A, John Haywood, Elisabeth Drake, et al. "On the road in 2020 - A Life Cycle Analysis of New Automobile Technologies." *web.mit.edu*. MIT, October 2000. Web. 5 Dec 2010. <http://web.mit.edu/energylab/www/pubs/el00-003.pdf>.

Waste Online, . "End of life vehicle and tyre recycling information sheet." *web.wasteonline.org.uk*. Waste Online, 2004. Web. 5 Dec 2010. < http://www.wasteonline.org.uk/resources/InformationSheets/vehicle.htm >

<u>7.2 U.S.Electric Car Operations and Infrastructure</u>

Addison, John. "5,000 Free Electric Car Charging Stations from California to New York." *Clean Fleet Report*. Clean Fleet Report, 3 Jun 2010. Web. 3 Dec 2010. <http://www.cleanfleetreport.com/cities/5000-free-electric-car-charging-stations-california-new-york-2/>.

Alspach, Kyle. "Mass to Get Electric Car Charging Stations." *Boston Business Journal*. Boston Business Journal, 6 Oct 2010. Web. 3 Dec 2010. <http://www.bizjournals.com/boston/stories/2010/10/04/daily34.html>.

Associated Press. "80 Electric charging stations planned in SC ." *Lake Wylie Pilot*. Lake Wylie Pilot News, 22 Nov 2010. Web. 3 Dec 2010. <http://www.lakewyliepilot.com/2010/11/22/929778/80-electric-car-charging-stations.html>.

Dutton, Rachel. "Are Electric Vehicles Really the Better Choice? Usually." Environmental Defense Fund, Innovation Exchange. Environmental Defense Fund, 15 June, 2010. Web. 3 Dec 2010. <http://blogs.edf.org/innovation/2010/06/15/are-electric-vehicles-really-the-better-environmental-choice-usually/>.

Hamilton, Tyler. "Lithium Battery Recycling Gets a Boost." *Technology Review*. MIT, 12 August 2010. Web. 3 Dec 2010. <http://www.technologyreview.com/energy/23215/>.

Jensen, Mark. "Whole Foods Leapfrogs Gas Stations with Electric Car Charging Station." *Tainted Green*. Green Business, 12 Apr 2010. Web. 3 Dec 2010. <http://www.taintedgreen.com/green-business/whole-foods-leapfrogs-gas-stations-with-electric-car-charging-station/000616>.

Knightstep, Jennifer. "Will you Invest in a Charging Station?" All Cars Electric. High Gear Media, 14, Oct 2009. Web. 3 Dec 2010. <http://www.allcarselectric.com/blog/1036668_will-you-invest-in-a-charging-station>.

LaMonica, Martin. "Electric Cars Seen as Killer App for Smart Grid." *Green Tech*. CNET.com, 20 Jun 2010. Web. 3 Dec 2010. <http://news.cnet.com/8301-11128_3-10269723-54.html>.

Leeds, David J. "Proposal for Boston." *Green Tech Grid:* Green Tech Media, 23 Feb 2010. Web. 4 Dec 2010. <http://www.greentechmedia.com/articles/read/the-networked-ev-smart-grids-and-electric-vehicles-first-step-california/>.

Moyer, Michael. "Dirty Truth about Plug in Hybrids." Scientific American. July 2010: 54-55. Print.

O'Brien, Bob. "Proposal for Boston." *Neighborhood Views*. North End Waterfront.com, 27 Aug 2010. Web. 3 Dec 2010. <http://www.northendwaterfront.com/home/2010/8/27/proposal-for-bostons-first-electric-vehicle-charging-facilit.html>.

O'Dell, John. "Tesla Owners Get Fast-Charge Station to Facilitate L.A. to San Francisco Trips." *Green Car Advisor*. Edmunds.com, 24 Feb 2010. Web. 4 Dec 2010. <http://www.allcarselectric.com/blog/1047586_video-2011-nissan-leaf-ev-navigation-system-demo>.

Pacific Gas & Electric 1. "Determine Where You'll Charge Your Car." *Electric Vehicles - Get Plug in Ready*. Pacific Gas & Electric, November 2010. Web. 3 Dec 2010. <http://www.pge.com/myhome/environment/pge/cleanair/electricdrivevehicles/pluginready/index.shtml>.

Pacific Gas & Electric 2. "Selecting The Charge Level That's Right for you." *Electric Vehicles - Get Plug in Ready*. Pacific Gas & Electric, 2010. Web. 3 Dec 2010. <http://www.pge.com/myhome/environment/pge/cleanair/electricdrivevehicles/pluginready/index.shtml>.

Pacific Gas & Electric 3. "Selecting assessing your home's charging ability" *Electric Vehicles - Get Plug in Ready*. Pacific Gas & Electric, 2010. Web. 3 Dec 2010.

<http://www.pge.com/myhome/environment/pge/cleanair/electricdrivevehicles/pluginready/index.shtml>.

Padgett, Marty. "Video: 2011 Nissan Leaf EV Navigation System Demo." *All Cars Electric Blog*. All Cars Electric, 28 Jul 2010. Web. 4 Dec 2010. <http://www.allcarselectric.com/blog/1047586_video-2011-nissan-leaf-ev-navigation-system-demo>.

Rye, Court. "First McDonald's with Electric Car Charger!" *Electric Vehicle Authority*. 6 Jul 2010, n. d. Web. 3 Dec 2010. <http://evauthority.com/first-mcdonalds-with-electric-car-charger/>.

Somalwar, Sunil. "A Case against the Electric Car." *Giving Directions*. Better World Club, 07 08 2008. Web. 4 Dec 2010. <http://www.betterworldclub.com/articles/DC_Case_Against_Electric_Car.htm>.

Squatriglia, Chuck. "EV Batteries will have lives beyond the road." *Autopia*. Wired Magazine, 24 Nov 2010. Web. 3 Dec 2010. <http://www.wired.com/autopia/2010/11/ev-batteries-will-have-lives-beyond-the-road/>.

Star Ledger News Desk. "Montclair to install first public electric car charging stations in N.J." *NJ.com*. North Jersey.com, 14 Sept 2010. Web. 3 Dec 2010. <http://www.nj.com/news/index.ssf/2010/09/montclair_to_charge_electric_c.html>.

Team Planet Green. "Can Electric Car Batteries Be Recycled?." Planet Hreen.com. N.p., 02 nov 2010. Web. 3 Dec 2010. <http://planetgreen.discovery.com/tech-transport/can-electric-car-batteries-be-recycled.html>.

Wikipedia. "Vehicle-to-Grid." *Wikipedia*. Wikipedia, 28 Nov 2010. Web. 4 Dec 2010. <http://en.wikipedia.org/wiki/Vehicle-to-grid>.

Woody, Todd 1. "Plans for Fast-Charging Stations Raise Concerns among California Utilities." *Green: A blog about Energy and the Environment*. New York Times, 28 Jan 2010. Web. 3 Dec 2010. <http://green.blogs.nytimes.com/2010/01/28/plans-for-fast-charging-stations-raise-concerns-among-california-utilities/>.

Woody, Todd 2. "California’s Bay Area ponies up for electric-car charging stations." *Emissions Mission*. Grist, 5 Aug 2010. Web. 3 Dec 2010. <http://www.grist.org/article/california-air-pollution-district-to-pay-for-electric-car-charging-stations>.

7.3 Electric Cars World Wide

Rogers, Simon. "Carbon emissions from cars: the US compared to other countries and by state." *DataBlog*. gardian.co.uk, 20 May 2010. Web. 7 Dec 2010. <http://www.guardian.co.uk/news/datablog/2009/mar/01/carbon-emissions-automotive-industry#>.

Wikipedia 1. "Nissan Leaf." *Wikipedia*. Wikipedia, 7 Dec 2010. Web. 7 Dec 2010. <http://en.wikipedia.org/wiki/Nissan_Leaf>.

Wikipedia 2. "Electric Vehicles: India." *Wikipedia.org*. Wikipedia, 4 Dec 2010. Web. 7 Dec 2010. <http://en.wikipedia.org/wiki/Electric_vehicle#India>.

Lakshman, Nandini. "Made in India: The 12,000 Electric Car." *World*. Time, 21 Jul 2009. Web. 7 Dec 2010. <http://www.time.com/time/world/article/0,8599,1911869,00.html>.

Quick, Darren. "U.S. Vehicle Emissions still almost double Europe and Japan." *Automotive*. Gizmag, 12 Jun 2010. Web. 7 Dec 2010. <http://www.gizmag.com/us-european-japanese-car-market-co2-pollution/15485/>.

Bradsher, Keith. "China Outlines Plans for Making Electric Cars." *Energy and Environment*. New York Times, 10 Apr 2010. Web. 7 Dec 2010. <http://www.nytimes.com/2009/04/11/business/energy-environment/11electric.html?_r=2>.

Nationmaster. "World Resources Institute. 2003." *Nationmaster.com*. World Resources Institute, 2003. Web. 7 Dec 2010. <http://www.nationmaster.com/graph/env_co2_emi-environment-co2-emissions>.

Innovation Europe Staff. "Electric Car - Portugal's Plan for E-Mobility." *Innovation Europe*. Innovation Europe, 14 Jul 2010. Web. 7 Dec 2010. <http://www.innovationeu.org/news/innovation-blog/0291-electric-car---portugal-s-plan-for-e-mobility.html>.

Fineren, Daniel. "Portugal to open electric vehicle network in 2011." *Reuters: Analysis and Opinion*. Reuters, 19 Oct 2010. Web. 7 Dec 2010.

<http://www.reuters.com/article/idUSTRE69I4G420101019>. EV Future. "Electric Vehicles - Bikes, Scooters, Motorcycles and Cars In India." *Prediction: three million electric vehicles by 2015*. EV Future, 17 Oct 2010. Web. 7 Dec 2010. <http://www.evfuture.com/>.

Pike Research. "Electric Vehicle Sales in Asia Pacific to Total 1.4 Million by 2015." *Environmental Expert*. Environmental Expert, 16 Nov 2010. Web. 7 Dec 2010. http://www.environmental-expert.com/resulteachpressrelease.aspx?cid=28518&codi=209075.

Admin. "Fiat Palio Weekend Electric Version Launched in Brazil." *International*. Wheelsphere, 19 Jul 2009. Web. 7 Dec 2010. <http://www.wheelosphere.org/fiat-palio-weekend-electric-version-launched-in-brazil/>.

7.4 Transportation Alternatives to the Electric Car (Matthew Reeves)

Buckingham, David A. "Steel Stocks in Use in Automobiles in the United States", USGS.gov. Accessed on 12/1/10. http://www.the-frugal-non-consumer.com/recycling-steel-facts.html

Gomez-Ibanez, Jose A. & Nancy Humphrey. Special Report 298, "Driving and the Built Environment", Pg. 27. June 2008.

O'Malley Greenberg, Jack. Forbes.com, "America's Cleanest Commute". September 9, 2009. Accessed on 11/5/10. http://www.forbes.com/2009/09/21/clean-commutes-cities-lifestyle-america-public-transportation.html

Vaughan, Adam. Guardian.co.uk, "City Dwellers Have Smaller Carbon Footprints". March 23, 2009. Accessed on 11/5/10. http://www.guardian.co.uk/environment/2009/mar/23/city-dwellers-smaller-carbon-footprints

Wiewel, Wim & Joseph Persky. Suburban Sprawl: Private Decisions and Public Policy. M. E. Sharpe, Inc, Armon, NY. 2002. Page 101. Print.

"Public transit vs. Highways", 2001 Sprawl Report. Sierraclub.org Accessed on 11/27/10 http://www.sierraclub.org/sprawl/report01/transitvshighways.asp

"Climate Change", completestreets.org. Accessed on 11/27/10. http://www.completestreets.org/complete-streets-fundamentals/factsheets/climate-change/

"Table 1A-1", American Housing Survey for the United States: 2007. September 2008. http://www.census.gov/prod/2008pubs/h150-07.pdf

"FAQ's", American Transit Builders Association of America. Artba.org Accessed on 11/27/10. http://www.artba.org/about/faqs-transportation--general-public/faqs/

"Does Dense Make Sense? Part 3", boulderblueline.com, 2010. Accessed on 12/1/10

www.boulderblueline.org/2010/7/28/does-dense-make-sense-part-3-density-and- carbon-footprint/

"Greenroads", pavementinteractive.org. Accessed on 12/1/10.

http://pavementinteractive.org/images/6/6c/Greenroads_summary.pdf

"A Look at Recycling Steel Facts and Carbon Footprint", the-frugal-non-consumer.com

Accessed on 12/1/10 http://www.the-frugal-non-consumer.com/recycling-steel-facts.html

8. FIGURES

8.1 Electric Car Manufacturing and Disposal

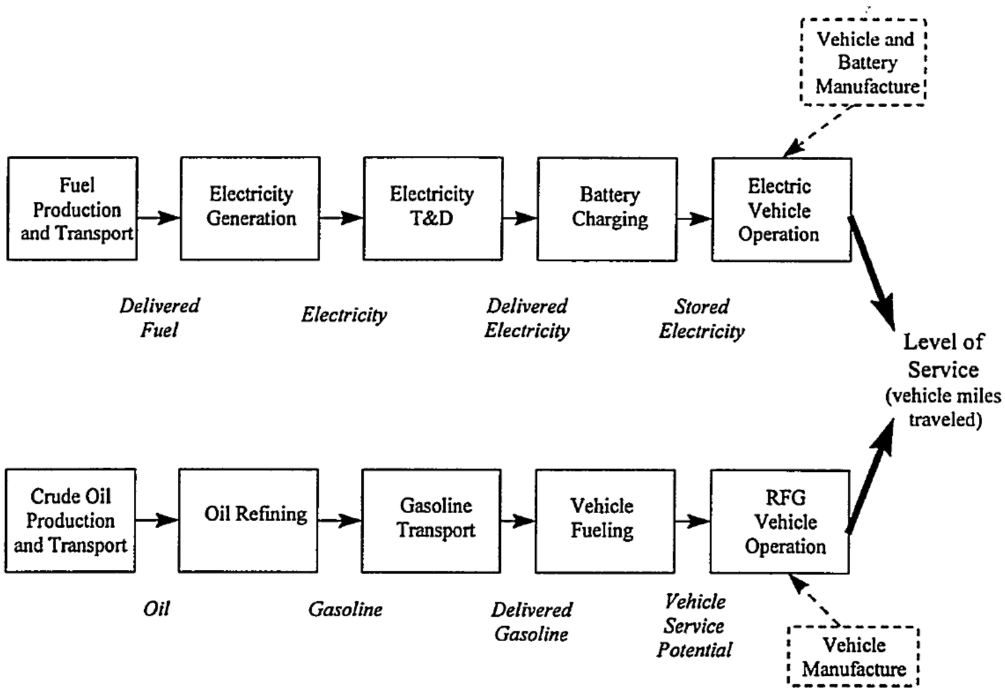

Figure AM1: Showing the Life Cycles of EV and CV

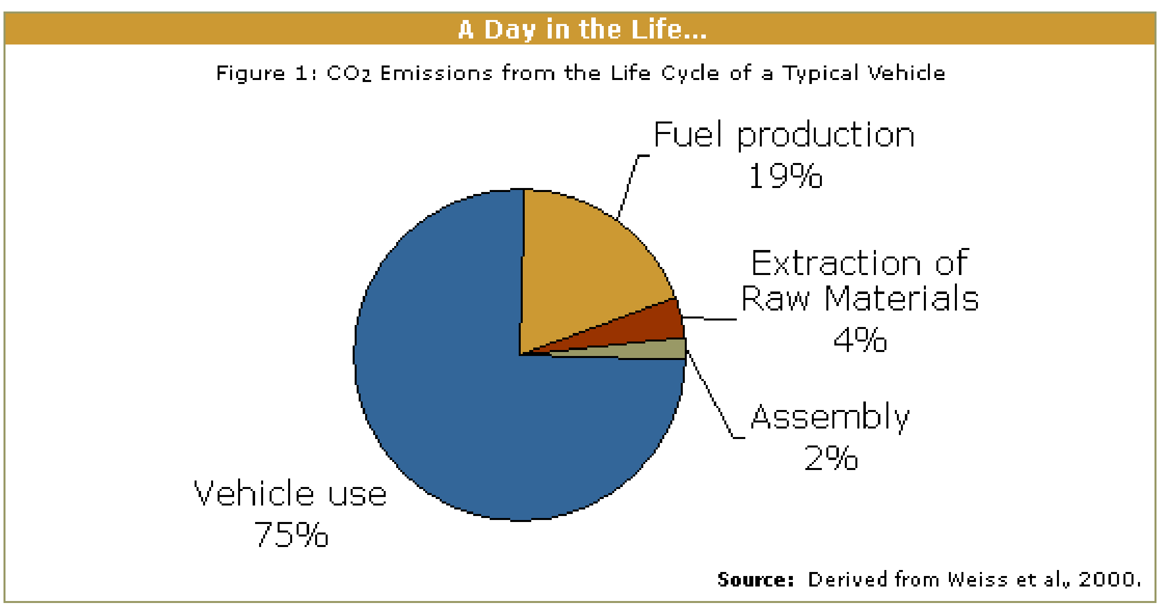

Figure AM2: Emissions based on the lifecycle of a typical vehicle

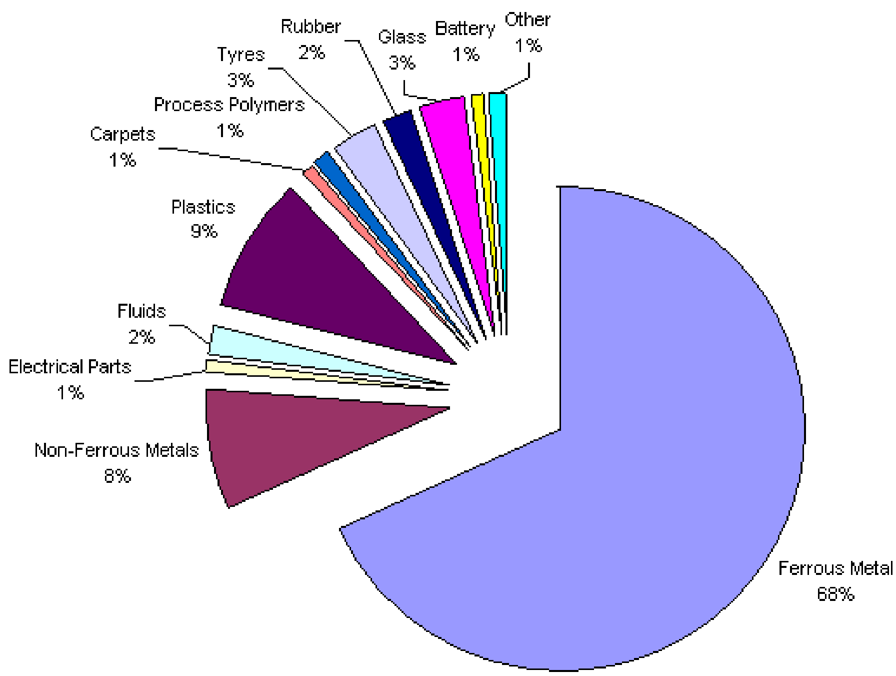

Figure AM 3 – Showing percent of material composition in a typical car.

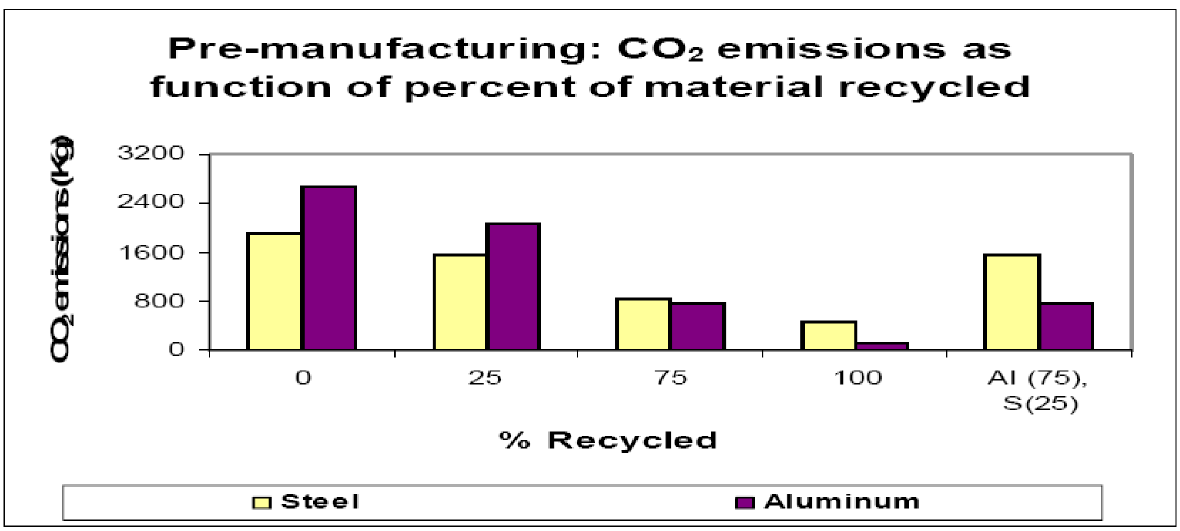

Figure AM4: CO2 emissions in pre manufacturing of EV

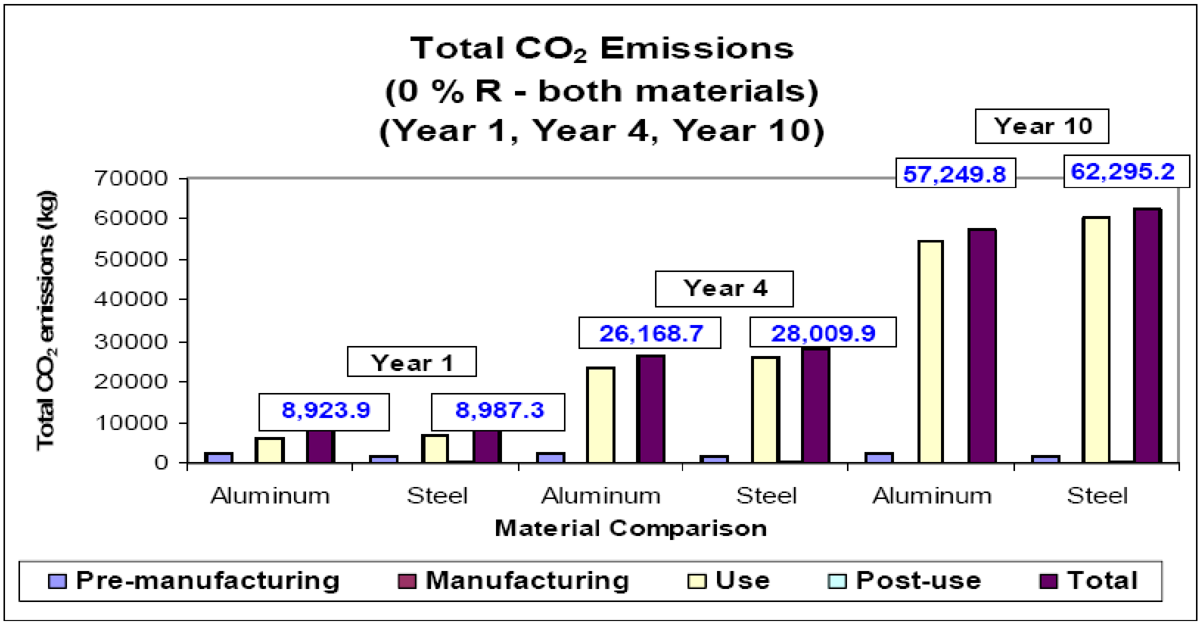

Figure AM5: CO2 emissions in all stages of an EV LCA

Airborne Emissions (lb/1000 tons)								
Material	NO_x	SO_x	CO	Pb	TSP	CO_2	CH_4	NMVOC
Steel Parts**	390	14200	1.89E+05	0.028	814	6.72E+06	710	288
Iron Castings	22500	38800	662	16	3730	9.29E+06	35.1	114
Aluminum Parts***	18200	7.11E+04	1820	0.594	6.31E+04	8.08E+06	183	286
Copper/Brass	19900	8.40E+05	11200	201	92400	8.12E+06	210	2470
Plastics	8200	45000	1300	NC	4000	7.82E+06	290	490
Styrene Butylene Rubber	23000	80400	3710	0.3	10200	1.99E+06	709	12600
Float Glass	11100	14100	490	0	2500	2.10E+06	45	400
Fiberglass	25400	25600	3100	0	1200	1.70E+06	37	35
Lead	5080	16900	245	238	1110	2.28E+06	29.8	52

* Zinc and powder metal were not characterized. No emissions of PM_{10} or N_2O were included.
** The same characterization was used for stainless, mild, HS, and other steel.
*** Includes a mix of cast and wrought aluminum.
NC: Not Characterized

Figure AM6: Emissions based on manufacturing materials

	Polypropylene	Polyester	High Density Polyethylene	Weighted Average
Energy (10^6 Btu/ton)	28.4	74.6	33.0	**42.8**
Residuals (lbs/ton)				
NOx	5.4	14.2	6.3	**8.2**
SOx	30.0	79.0	35.0	**45.0**
TSP	2.64	7.04	3.0	**4.0**
CO	0.9	2.2	1.0	**1.3**
VOC	0.05	1.54	0.06	**0.49**
CO_2	5,200.0	13,600.0	6,000.0	**7,817.0**
Methane	0.19	0.5	0.22	**0.29**
Lead	0.0008	0.0021	0.0009	**0.0012**
Other				
Gas (Propylene)	0.4	0	0	**0.2**
Share of Year 2000 Plastic	0.24	0.14	0.1	

Figure AM7: Energy and Airborne emissions per ton of plastic output

Figure AM8: Proposed metrics for major categories in sustainable manufacturing

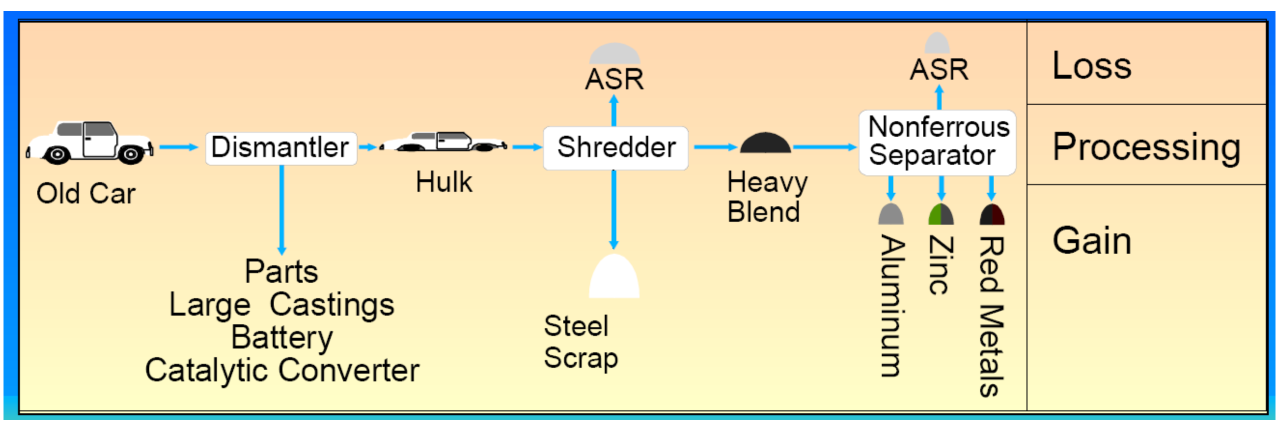

Figure AM9: Recycling Process Overview

8.2 Electric Car Operations and Infrastructure

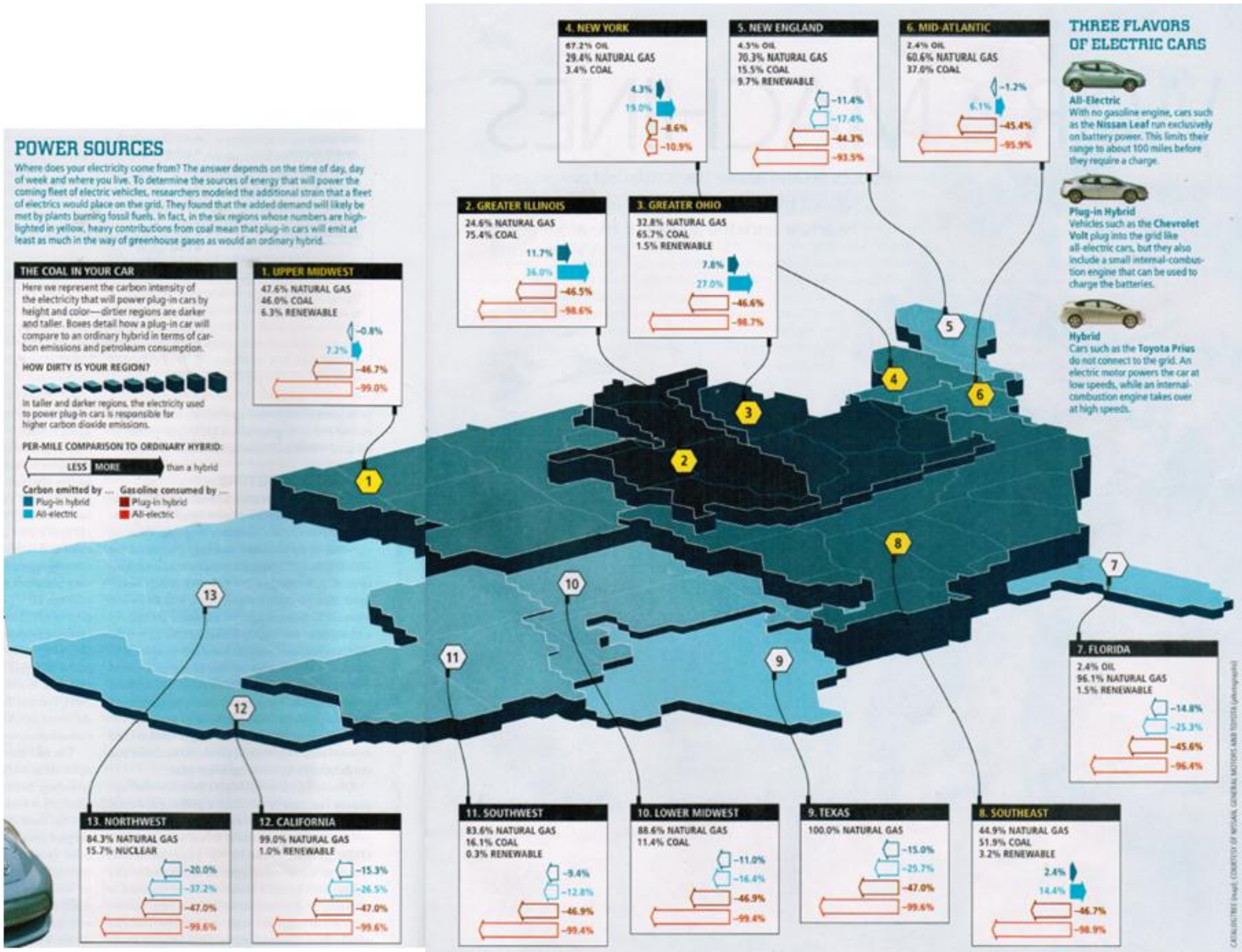

Figure GP1. Cleanliness of Electric Power in 13 US Regions (Scientific American, Department of Energy)

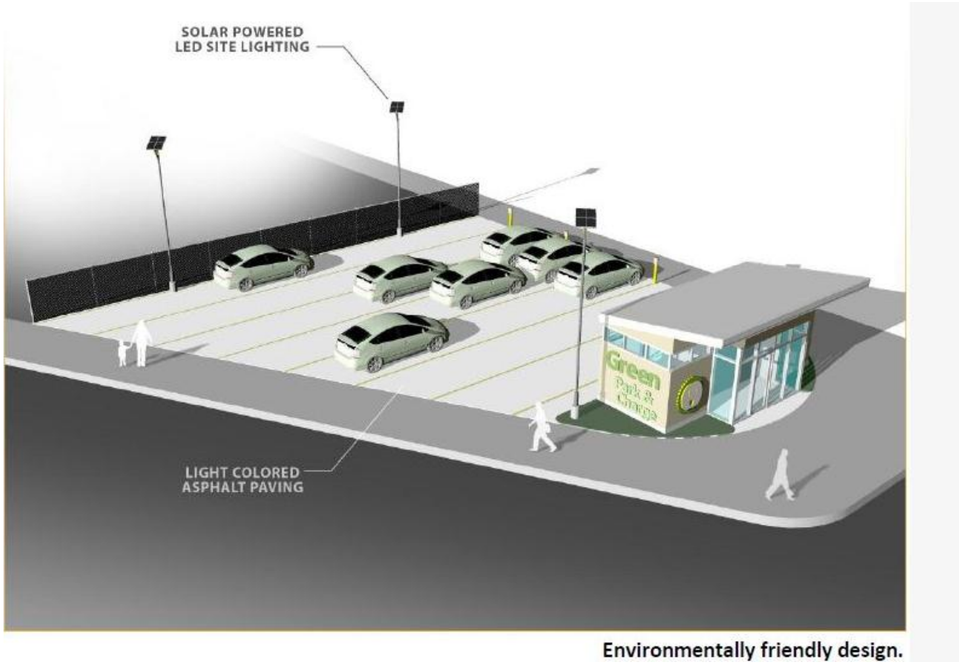

Figure GP2. Vehicle Charging Station Concept on Urban Brownfield (Dinosaur Capital Partners)

8.3 Electric Cars World Wide

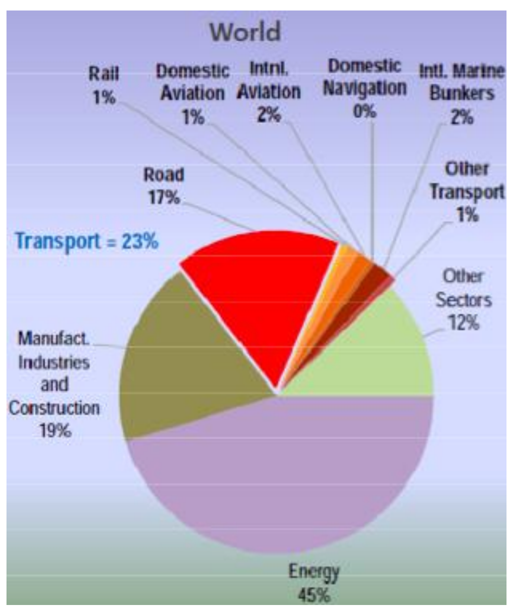

Figure AH1 Transport's Share of CO2 emissions from fuel combustion.

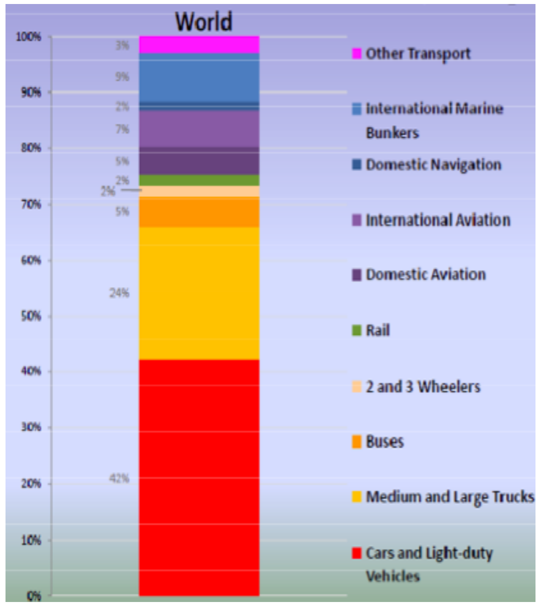

Figure AH2 Share of transport CO2 emission 2005.

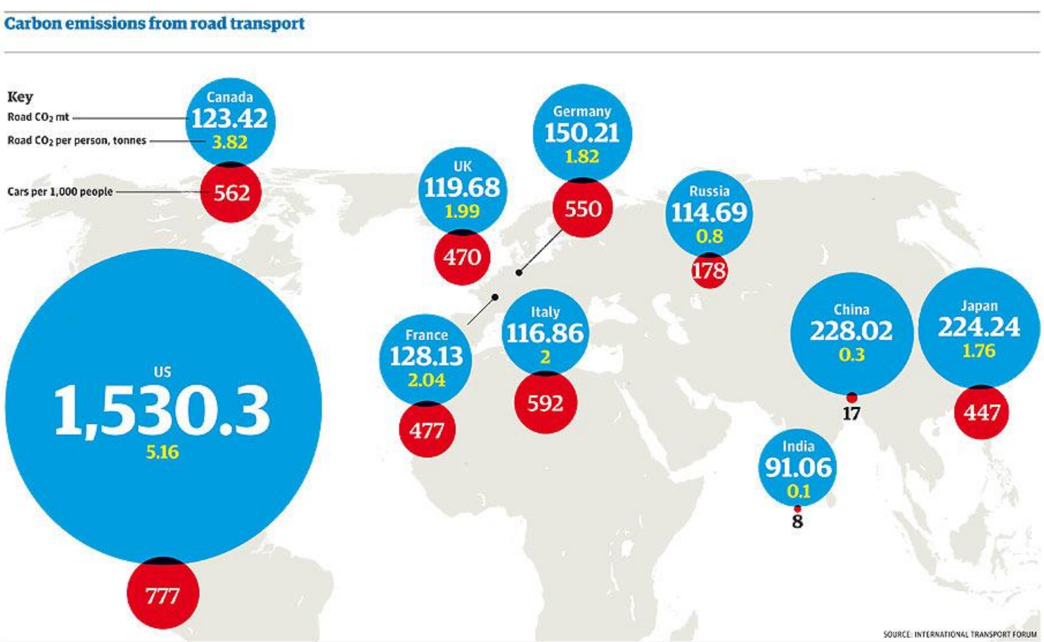

Figure 3) Carbon Emissions from Road Transport Worldwide

8.4 Transportation Alternatives to the Electric Car

No figures were required for this section.