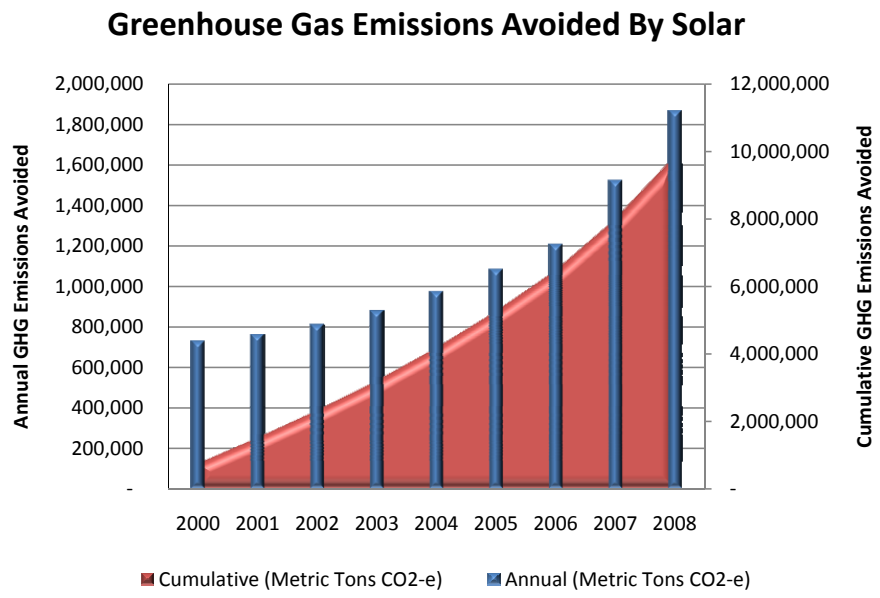
The right energy source would change the way the United States of America operates. Imagine our country when solar and other renewable energy sources supply over half of our electricity.

Our air will be cleaner. *"An average U.S. household uses 830 kilowatt-hours (kWh) of electricity per month. On average, producing 1000 kWh of electricity with solar power reduces emissions by nearly 8 pounds of sulfur dioxide, 5 pounds of nitrogen oxides, and more than 1,400 pounds of carbon dioxide. During its projected 28 years of clean energy production, a rooftop solar energy system will avoid conventional electrical plant emissions of more than half a ton of sulfur dioxide, one-third a ton of nitrogen oxides, and 100 tons of carbon dioxide. Solar electricity is clearly a wise energy investment with great environmental benefits!" SEIA site.*

The cleaner air would lead to fewer deaths from respiratory and cardiovascular illness, fewer deaths from lung cancer, lower rates of infant mortality, lower rates of heart disease, less inflammation of the lungs, and less severe asthma leading to less hospitalization for asthma related problems in children. Cleaner air will not only lead to an improved quality of life, but will also decrease medical costs for our country. (References below)

In addition to reducing pollutants, replacing fossil fuels with clean renewable energy will mitigate the risks of too much carbon dioxide in the air. Electricity generation represents 41% of our carbon dioxide emissions (EIA, 2009). By switching to renewables, we will begin to allow the earth to regain her balance with less man made carbon dioxide emissions thus minimizing the largest environmental experiment in history. Every house with a PV system reduces the greenhouse gas emissions by approximately as much as removing a car from the road. Likewise, every megawatt of solar installed displaces 1,000 metric tons of carbon dioxide per year which is the average annual emissions of 50 US citizens or 180 cars on the road.



In addition to a cleaner environment, creating a domestic supply of energy makes financial sense. America will no longer need to send 110 billions of dollars a year over seas ($25 billion a year goes to the Persian Gulf alone) to areas of the world that threaten our security. (NRDC) We will no longer need to consider compromising our ideals to keep on friendly terms with oil producing nations. Our energy will be locally produced with generation distributed. This will make our energy secure from both forces outside the country and terrorist attacks inside our homeland. The United States needs a low cost, non-polluting, abundant, domestically produced energy source and we need it soon.

The current administration recognizes the importance of renewables and in particular solar energy.

"*So we have a choice to make. We can remain one of the world's leading importers of foreign oil, or we can make the investments that would allow us to become the world's leading exporter of renewable energy. We can let climate change continue to go unchecked, or we can help stop it. We can let the jobs of tomorrow be created abroad, or we can create those jobs right here in America and lay the foundation for lasting prosperity*."
-President Obama, March 19, 2009

"*Today, America produces less than 3 percent of our electricity through renewable sources like wind and solar -- less than 3 percent. Now, in comparison, Denmark produces almost 20 percent of their electricity through wind power. We pioneered solar technology, but we've fallen behind countries like Germany and Japan in*

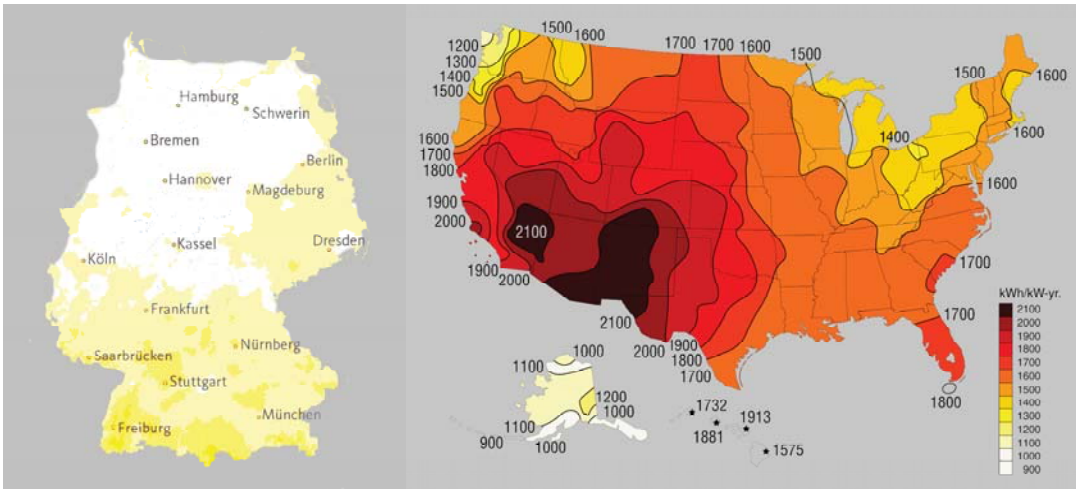
generating it, even though we've got more sun than either country." –President Obama, April 22, 2009

Many renewable energy sources have an important part to play in our future energy mix. However, of all the renewable energy sources available, only solar has the potential to fill all of our energy needs. To power the planet we need ~16 TW of electricity, and by 2030 ~30 TWs. Other renewables have limited practical potential: hydro electricity is limited to 2 TW, geothermal to 3 TW, and wind energy to 5 TW. Solar has ~600 TW of obtainable energy and one hundred twenty thousand terawatts of solar power hit the earth. "More solar energy hits the earth in one hour than all the energy the world consumes in a year." Just five minutes of sunlight on the United States has enough solar energy to satisfy our energy demand for a month. (Nate Lewis Powering the Planet 2007, http://nsl.caltech.edu/energy.html)

This important topic sits at the intersection of five of the seven areas of critical use already identified by NIST and indirectly the other two (civil infrastructure and complex networks & complex systems both through energy delivery). The topics of energy, manufacturing, and sustainability all encompass the investing in high risk/high reward photovoltaic designs that will allow us to be competitive with other nations. Interestingly the problems of energy and fresh water supplies are very intertwined. For example, with clean inexpensive energy, clean water can be obtained from salt water. In addition, solar power uses 98% less water per mWh generated than even the most efficient natural gas generation. Thus, the proposed topic is also related to the NIST TIP topic of ensuring a future water supply. The topic of nanomaterials and nanotechnology is also overlapping with this topic proposal since many of the high risk/high reward approaches to low cost solar electricity are based on nanoengineering. For example my company's technology, Bandgap Engineering, is a patent pending design using silicon nanowires to increase the absorption coefficient of silicon by 1000 times thus increasing the photovoltaic conversion efficiency of silicon and decreasing the cost of electricity.

The country that leads in renewable energy will be the country that leads in the next century. A relatively small investment now will save much more money in the future. Although the solar cell was invented in the United States 54 years ago, we have fallen behind other countries in both production and manufacturing of solar cells. Less than a decade ago we had 40% of the worlds PV manufacturing capacity. Today we only manufacture about 8% of the world solar cells. The world photovoltaic market has averaged an annual growth of 35% per year, while the US market has only grown 8% per year. Germany, for example leads United States in installations and manufacturing of photovoltaics, even though the sun is much less intense in Germany compared to the United States.

Solar Resources: Germany vs. United States
(in kWh of solar electricity produced per kW of solar capacity)



Luckily, it isn't too late to lead in photovoltiacs. We are at a critical time for PV development. Solar electricity, the way it is currently measured, costs 30 cents per kWh compared to 10-20 cents per kWh for electricity produced by burning fossil fuels. This cost means that for most of the country, and in fact the world, solar electricity is not yet cost competitive. Therefore the market is limited to only those that recognize the benefits of solar electricity over conventional energy sources, very selective markets where PV is cost competitive, and markets that are subsidized. These limitations explain why solar electricity accounts for less than 1/10th of 1% of the energy production in the United States. We are at a unique time where soon solar electricity will become cost competitive with more traditional sources of electricity *without subsidies*. When this cross over in costs occurs, the solar electric market will explode. At this point in time, whichever country (ies) is (are) best equipped to meet this growing need, will become the Middle East of the next century. They will begin by having a slight advantage over others: more government subsidies, more trained workers, more manufacturing capabilities, or better technology. This advantage will allow them to make use of the boom in solar electricity and make large profits from selling cells to other countries not in the lead. This money can then be reinvested into training their people, building more manufacturing, and R&D to improve their technology, thus further insuring their lead in energy production. After the lead has been established, it will be difficult for other countries to compete. However now, before the cross over in costs has occurred and the market is still small, all countries have a chance for being ready for the rise of solar electricity.

United States has always been the land of innovation. It is in our blood. As the person in charge of hiring for a solar company, I can say with confidence that many creative and bright scientists and engineers wish to apply their technical expertise to improve photovotlaics. So our problem isn't our talent pool.

Although other nations may have temporarily seized leadership in solar technology, there is no limit of creative ideas to help us leap frog others in developing commercially viable large-scale solar technology. The last call for ARPA-E for solutions to our energy problem had over 3,700 applications for 37 awards. Many companies are working hard to make photovoltaics cost competitive with more conventional energy sources and believe that they have the answer. For example, Wakonda Technologies is developing a novel process for growing single-crystal-like thin films of semiconductor materials on commodity metal foil. They will deliver flexible lightweight photovoltaic modules for the mobile power and building-integrated solar markets with efficiencies above the efficiency of crystalline silicon but with the low-cost structure of thin film PV. With additional funding from NIST, Wakonda will be able to add resources to enable even lower cost processes and materials with no adverse effect on efficiency. In addition, Bandgap Engineering is nanoengineering silicon for high efficiency. Without increasing manufacturing costs, we can improve solar cell efficiency from 18% to 25% for an estimated price of 14 cents per kWh. Current venture capital backed funding is helping us apply our technology to wafer based cells. However, with more resources, this same technology can be applied to deposited silicon materials for a higher efficiency and low cost option. A third example is Solar Junction. Solar Junction is a developer of next-generation, high-efficiency multi-junction solar cells. Solar Junction departs the current metamorphic-based roadmap by developing a lattice-matched architecture directly extendible to greater than 3 junction solar cells towards the pursuit of 50+ % efficiency solar cells with no new materials science development required or epitaxial material cost increases. If Solar Junction were to receive TIP funding, our technology development would be accelerated producing a 45% and 50% efficiency multi-junction solar cell by 2012 and 2016 respectively resulting in a superior Levelized Cost of Energy (LCOE) for Concentrating Photovoltaics (CPV) as compared to alternative PV approaches.

So, our problem also isn't a shortage of ideas. What limits the United States of America in becoming the leader of the energy for the next century is money to fund advanced concepts for high efficiency solar electricity. Renewables and photovoltaics in general are under funded. The Environmental Law Institute calculates $72 billion in subsidies for fossil fuels compared to $29 billion for renewables of which over half is for corn ethanol from 2002 to 2008. The Department of Energy (DOE) through the Solar Energy Technologies Program (SETP) funds a range a programs aiming to promote solar energy development at various stages of the technology development pipeline. There are several programs aimed at promoting proven technologies through the system development and manufacturing stages, including the PV Incubator, Technology Pathway Partnerships, PV University Product & Process, Supply Chain and PV Manufacturing Initiative. Collectively these programs consume the vast majority of the SETP budget. additionally, virtually all new funding requested in FY10 and as part of

ARRA is focused on downstream initiatives such as Systems Integration, Market Transformation, Loan Guarantee Program etc.

SETP does fund two programs aimed at earlier stage technologies: the PV Next Gen program for device & process proofs of concept, the PV Pre-Incubators for prototype development. These programs are strong and vibrant and we fully support their continuation, although we note that long range R&D (e.g. >7 years), consumes only 10% of the SETP budget. Moreover, the Next Gen Program supported only 25 recipients in 2008 with an average award of under one million dollars and is only funded every other year. The Pre-Incubator Program is an annual program that funded 13 recipients in 2008 with an average award of $500,000.

We would like to see NIST supplement these programs with added funding for solar-specific early stage material & device concept development and proof of concept development. Put simply, many high quality, high potential initiatives are underway which could use the additional funding for high technical risk and high gain projects. In addition, there is added benefit to having more than one funding agency fund such an important area critical to the success of our country. Having more than one agency supporting similar areas of development offers advantages such as 1) more funding to compliment each other, 2) funding opportunities at different times throughout the year, (If we just added funds to DOE (also a good idea) a company may have to wait a full year in the case of the pre-incubator and two years for the Next Gen Program before applying and then another 6-9 months before getting money for their development.), 3) varying perspective on which programs and approaches should receive funding., and 4) different types of support associated with the grant that are unique to each funding agency – publicity, fabrication facilities, testing facilities, and advisors.

As the political landscape evolves, many in the solar field are growing concerned that the US is focusing excessively on very short-term investments. It has become apparent that within the next 7 to 10 years, the US will largely depend on a massive shift from coal to natural gas as part of its strategy to meeting its CO2 reduction obligations. Further improvements, however, will require a more dramatic change in our energy infrastructure – including a massive deployment of very low carbon generation capacity.

Although the importance of funding high risk high reward solar energy is widely recognized, the funding opportunities in the United States are inadequate to address the magnitude of the challenge. Venture capital and established companies help, but are focused on those technologies that have a lower technical risk and which will be ready for market in the near future. In addition, these funding sources are limited and have declined due to the state of the economy; federal agencies cannot continue to rely as heavily on venture and large corporations to support solar technology development in the next few years. Yet these next few years are critical – if the United States is to successfully accelerate a transition strategy away from carbon based fuels in 10 years and become an energy leader, then it must invest in research and development of disruptive technologies that will eventually make solar

electricity cost competitive *without* subsidies and this investment needs to happen now.

Let's encourage America to do what we do best: innovate.

With my hopes for our future,

Marcie R. Black

References

Health risks of pollution –

1. Dominici F, McDermott A, Zeger SL, Samet JM. On the Use of Generalized Additive Models in Time-Series Studies of Air Pollution and Health. Am J Epidemiol 2002; 156:193-203.
2. Hong, Y.-C., Lee J.-T., Kim, H., Ha, E.-H., Schwartz, J., and Christiani, D.C. Effects of Air Pollutants on Acute Stroke Mortality. Environ Health Perspect 2002; 110:187-191.
3. Tsai SS, Goggins WB, Chiu HF, Yang CY. Evidence for an Association Between Air Pollution and Daily Stroke Admissions in Kaohsiung, Taiwan. Stroke 2003; 34: 2612-6.
4. Wellenius GA, Schwartz J, Mittleman MA. Air Pollution and Hospital Admissions for Ischemic and Hemorrhagic Stroke Among Medicare Beneficiaries. Stroke 2005; 36:2549-255.
5. Pope and Dockery, 2006.
6. D'Ippoliti D, Forastiere F, Ancona C, Agabity N, Fusco D, Michelozzi P, Perucci CA. Air Pollution and Myocardial Infarction in Rome: a case-crossover analysis. Epidemiology 2003;14:528-535. Zanobetti A, Schwartz J. The Effect of Particulate Air Pollution on Emergency Admissions for Myocardial Infarction: a multicity case-crossover analysis. Environ Health Perspect 2005; 113:978-982.
7. Ghio AJ, Kim C, Devlin RB. Concentrated Ambient Air Particles Induce Mild Pulmonary Inflammation in Healthy Human Volunteers. Am J Respir Crit Care Med 2000; 162(3 Pt 1):981-988.
8. Metzger KB, Tolbert PE, Klein M, Peel JL, Flanders WD, Todd K, Mulholland JA, Ryan PB, Frumkin H. Ambient Air Pollution and Cardiovascular Emergency Department Visits in Atlanta, Georgia, 1993-2000. Epidemiology 2004; 15: 46-56.
9. Tsai, 2003.
10. Wellenius GA, Schwartz J, and Mittleman MA. Particulate Air Pollution and Hospital Admissions for Congestive Heart Failure in Seven United States Cities. Am J Cardiol 2006; 97 (3):404-408. Wellenius GA, Bateson TF, Mittleman MA, Schwartz J. Particulate Air Pollution and the Rate of Hospitalization for Congestive Heart Failure among Medicare Beneficiaries in Pittsburgh, Pennsylvania. Am J Epidem 2005; 161:1030-1036.

11. Van Den Eeden SK, Quesenberry CP Jr, Shan J, Lurmann F. Particulate Air Pollution and Morbidity in the California Central Valley: a high particulate pollution region. Final Report to the California Air Resources Board, 2002.
12. Lin M, Chen Y, Burnett RT, Villeneuve PJ, Kerwski D. The Influence of Ambient Coarse Particulate Matter on Asthma Hospitalization in Children: case-crossover and time-series analyses. Environ Health Perspect 2002; 110:575-581.
13. Norris G, YoungPong SN, Koenig JQ, Larson TV, Sheppard L, Stout JW. An Association Between Fine Particles and Asthma Emergency Department Visits for Children in Seattle. Environ Health Perspect 1999;107:489-493.
14. Tolbert PE, Mulholland JA, MacIntosh DD, Xu F, Daniels D, Devine OJ, Carlin BP, Klein M, Dorley J, Butler AJ, Nordenberg DF, Frumkin H, Ryan PB, White MC. Air Quality and Pediatric Emergency Room Visits for Asthma in Atlanta, Georgia. Am J Epidemiol 2000; 151:798-810.
15. Slaughter JC, Lumley T, Sheppard L, Koenig JQ, Shapiro, GG. Effects of Ambient Air Pollution on Symptom Severity and Medication Use in Children with Asthma. Ann Allergy Asthma Immunol 2003; 91:346-353.
16. Dockery DW, Pope CA III, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG, Speizer FE. An Association Between Air Pollution and Mortality in Six U.S. Cities. NEJM 1993; 329:1753-1759. Pope CA, Thun MJ, Namboodiri MM, Dockery DW, Evans JS, Speizer FE, Heath CW. Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. Adults. Am J Respir Crit Care Med 1995; 151:669-674.
17. Pope CA III. Epidemiology of Fine Particulate Air Pollution and Human Health: biological mechanisms and who's at risk? Environ Health Perspect 2000;108: 713-723.
18. Lin S, Munsie JP, Hwang SA, Fitzerald E, Cayo MR. Childhood Asthma Hospitalization and Residential Exposure to State Route Traffic. Environ Res 2002; 88:73-81.
19. Gauderman WJ, Vora H, McConnell R, Berhane K, Gilliland GF, Thomas D, Lurmann F, Avol E, Kuenzli N, Jarrett M, Peters J. Effect of Exposure to Traffic on Lung Development from 10 to 18 Years of Age: a cohort study. Lancet 2007; 369:571-577.
20. Gauderman WJ, Gilliland GF, Vora H, Avol E, Stram D, McConnell R, Thomas D, Lurmann F, Margolis HG, Rappaport EB, Berhane K, Peters JM. Association between Air Pollution and Lung Function Growth in Southern California Children: results from a second cohort. Am J Respir Crit Care Med 2002;166:76-84.
21. Gauderman WJ, Avol E, Gilliland F, Vora H, Thomas D, Berhane K, McConnell R, Kuenzli N, Lurmann F, Rappaport E, Margolis H, Bates D, Peters J. The effect of air pollution on lung development from 10 to 18 years of age. NEJM 2004; 351:1057-1067.
22. Churg, A Brauer, M, Avila-Casado, MdC, Fortoul TI, Wright JL. Chronic Exposure to High Levels of Particulate Air Pollution and Small Airway Remodeling. Environ Health Perspect 2003; 111: 714-718.
23. Pope CA III, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, Thurston GD. Lung Cancer, Cardiopulmonary Mortality, and Long-Term Exposure to Fine Particulate Air Pollution, JAMA 2002; 287(9):1132-1141.
24. Pope CA III, Burnett RT, Thurston GD, Thun MJ, Calle EE, Krewski D, Godleski JJ.

Cardiovascular Mortality and Year-round Exposure to Particulate Air Pollution: epidemiological evidence of general pathophysiological pathways of disease. Circulation 2004; 109:71-77.