

GIVE NEW APPLICATIONS OF PIEZOELECTRIC POWER A CHANCE: TECHNOLOGICAL INNOVATIONS FROM AN EVOLVING ALTERNATIVE ENERGY AREA OFFER OPPORTUNITIES IN THE ENVIRONMENTAL AND FINANCIAL MARKETS

Kimberly E. Diamond

A science fiction-like alternative energy called piezoelectricity is endeavoring to become mainstream. Globally, recent groundbreaking scientific achievements in piezoelectric technology have enabled the kinetic energy produced from pedestrians and vehicles alike to be transformed into clean energy. Innovations in this area could have a profound impact in the sustainable development space, as well as in the project finance and investment banking arenas. Unfortunately, certain skeptics from the scientific community—particularly the engineering sector—are stampeding to quash international interest and support for these state-of-the-art developments, calling these breakthroughs and the piezoelectric technology behind them rubbish and a complete hoax. True, the quest to improve the revolutionary developments in piezoelectric flooring, as well as piezoelectric roadways, railways, and runways (collectively, “vehicular thoroughfares”), by making them more efficient and commercially viable for consumer consumption may be time- and research-intensive, causing the race to refine this technology to be more akin to a cross-country marathon than a mere sprint. The current evolution of piezoelectric technology, though, is arguably similar to that of solar power. For this reason, inventions such as piezoelectric flooring and vehicular thoroughfares may have a bright future, rather than merely being classified as nonsensical gadgetry responsible for draining the scientific community and investors alike of resources that could be better directed elsewhere. Moreover, in the future, loans used for the financing of piezoelectric projects domestically and abroad could potentially serve as the collateral foundation for the creation of novel breeds of asset-backed securities, using structuring, techniques, and methodologies from the securitization area. By providing background about scientific advances in piezoelectrics worldwide,

analogizing the state of piezoelectrics today to that of solar power during yesteryear, and addressing the primary arguments of the aforementioned skeptics and like-minded cynics (collectively, the “Piezoelectric Pessimists”), this article argues that the allegations from the Piezoelectric Pessimists generally lack merit, and that advances enabling piezoelectric devices to be incorporated into today’s infrastructure as sustainable building materials are worthy of public endorsement.

Status of Scientific Research in Piezoelectrics Globally

Physicists and scientists actually have known about piezoelectricity for decades, as French scientists discovered this technology in the 1880s. The term “piezoelectricity” originates from the Greek words “piezo” or “piezein,” which mean “to squeeze or press.” In simplistic terms, piezoelectricity is the ability of certain materials, such as quartz crystals and select ceramics, to generate an electrical charge when a form of mechanical pressure is applied. From the applied charge, voltage is generated across the material. When no force is applied to these materials, no electric charge is generated. Examples of ordinary devices that use piezoelectrics are quartz watches, motion detectors, and sonar.

Technology in the field of piezoelectrics has evolved rapidly during the last several years in the United States and abroad, particularly in the areas of piezoelectric pedestrian tiles and flooring and vehicular thoroughfares. Within the last five years alone, prestigious academic institutions in the United States, including Duke University, the University of Michigan, and Massachusetts Institute of Technology (MIT), have been homes to breakthroughs in piezoelectric flooring technology. For instance, in July 2004, Duke University’s Andrew Katz, an engineering student, published a paper summarizing the results of a physics project entitled “Residential Piezoelectric Energy Sources.” The paper, which hypothesizes the DELTA Smart House, a structure built with piezoelectric cable in its floors, concludes that the use of a piezoelectric transducer can act as a voltage source and can multiply voltage by several orders of magnitude when certain circuits are used. In summer 2007 at MIT’s School of

Architecture and Planning, graduate students James Graham and Thaddeus Jusczyk applied their research to design a piezoelectric floor that won first place in a competition by Holcim Foundation for Sustainable Construction in Zurich, Switzerland. Graham and Jusczyk are attributed with coining the phrase “crowd farm” to refer to harvesting energy from groups of people by accessing the mechanical energy they generate when walking or jumping onto an electricity source. Perhaps most notably, in 2006, the University of Michigan’s School of Art and Design’s Elizabeth Redmond based her design thesis on a piezoelectric flooring project. This project has now grown into POWERleap, an alternative energy company that Ms. Redmond co-founded with Mr. Katz. The company designs piezoelectric flooring that generates electricity from pedestrian foot traffic. To assist in the further research and development of its product, POWERleap recently has teamed up with the University of Michigan’s Department of Materials Science and Engineering’s Professor Max Shtein, a scientist who has been honored by the U.S. Office of Science and Technology for developing novel ways to make the next generation of energy-efficient lighting devices.

Similar revolutionary breakthroughs in piezoelectric devices have also occurred within the last several years at highly respected institutions of higher education in Japan and Israel. As illustration, in 2006, the East Japan Railway Company (JR East) launched a collaborative effort with researchers from Keio University—one of the most esteemed universities in Japan—to develop piezoelectric pads that could be embedded in floors under the ticket gates in Tokyo Station. More recently, at Technion—Israel Institute of Technology, Professor Haim Abramovich, a member of the Faculty of Aerospace Engineering, and Dr. Lucy Edery-Azulay spearheaded Innowattech, a company that has developed new breeds of piezoelectric generators for roadways, railways, runways, and pedestrians that are capable of harvesting kinetic energy from weight, motion, vibration, and temperature changes. These generators can also transfer this harvested energy directly into existing power lines for street lighting, or channel it into the energy grid. Currently, Innowattech is designing a hybrid system for

cities with heavy foot traffic and busy intersections, wherein energy from pedestrians and vehicles alike can be harvested simultaneously.

In terms of taking piezoelectric devices out of a pure laboratory environment and placing them in public forums, dynamic strides from the scientists, designers, and researchers noted above have been made worldwide within the last several years alone. Examples of domestic installations of these devices include Ms. Redmond’s successfully installing in a stretch of sidewalk at the University of Michigan piezoelectric flooring containing LED lights that flicker when stepped upon. Ms. Redmond has also installed the POWERleap piezoelectric flooring product in a store in Chicago. Mr. Katz and Ms. Redmond plan to pilot test this flooring product in a high profile venue on the West Coast later this year. According to POWERleap estimates, the amount of energy that can be generated using this flooring is 1–5 watt hours per person, per square foot. This means that over a 100 meter stretch of sidewalk, in cities with heavy daily foot traffic, pedestrians can generate approximately 1 kilowatt (kW) (an amount equal to 1,000 watts) of electricity each hour.

Overseas, equally impressive piezoelectric installations have appeared. In early 2008, Japan witnessed JR East and Keio researchers reach their goal of successfully installing piezoelectric pads under ticket gates in Tokyo Station. Now, because of the heavy foot traffic from the high volume of passengers going through these gates, lamps in this station are lit with converted piezoelectric energy. Currently, Innowattech plans on debuting its first pedestrian project at the Tel Aviv railway station within the next few months, and subsequently unveiling similar projects elsewhere in the world. While the first stretch of electric roadway is still in the development and testing stages at Technion, Innowattech has stated that, based on its research, the company’s piezoelectric roadway system works optimally when there are at least 600 vehicles per hour in car and truck traffic, producing approximately 400 kilowatt-hours (kWh) of electricity from a 1 kilometer stretch of dual roadway traffic—enough energy to power 600–800 homes annually. Innowattech also has developed piezoelectric generators and storage

systems for piezoelectric railways and runways, so that energy from other types of large, moving vehicles such as trains and airplanes can be harnessed.

Solar Power Experienced a Similar Evolution

Comparatively, piezoelectric flooring and vehicular thoroughfares are experiencing an evolution similar to that which solar energy experienced. For approximately 100 years, solar energy devices were viewed with skepticism and were not well-received. The earliest known record of the conversion of solar radiation into mechanical power is attributed to the French mathematics instructor Auguste Mouchout, who began his solar work in 1860. Although Mouchout refined his device for over the next 20 years, the French government deemed his device a technical success, but a practical failure attributable to its cost relative to its efficiency. Because of a lack of funding, Mouchout returned to other academic pursuits. In 1870, one of the most influential engineers of the nineteenth century, John Ericsson, invented a novel, parabolic trough-shaped solar rays reflector. Though less expensive to construct than its dish-shaped counterparts, this device was also less efficient than such counterparts. In the early 1900s, Henry Willsie attempted to sell his flat-plate solar collectors on the open market. Plentiful amounts of oil and coal, stable markets, and an already-in-place infrastructure made solar power devices seem inconsequential. Concerns relating to durability, the high ratio of machine size to power output, and the initial investment cost caused potential investors to be deterred from purchasing Willsie's product.

Almost 50 years later, while conducting research on the potentialities arising from the use of silicon in electronics, in the mid 1950's, scientists at Bell Laboratories inadvertently created a solar cell far more efficient than other solar collectors that had been built to date. Unlike its predecessors, this solar cell could convert enough solar energy to power everyday electrical equipment. Through scientists' continued research, the Bell solar cell doubled in efficiency in under two years. Nevertheless, this device remained commercially unsuccessful because of its still less than

ideal efficiency and relatively high cost. For instance, in 1956, a one-watt cell cost approximately \$300. It was not until the Army, the Air Force, and NASA viewed solar cells as valuable for satellites and space ventures in the 1960s that the public took an active interest in solar power and its development. It was not until the early 1970s that with further funding, research, and design refinement the price of a solar cell was lowered from approximately \$100 per watt to \$20 per watt. Almost 40 years later, the solar power industry has grown exponentially. Today, due to their price of solar cells continued to drop, solar cell devices are now the least expensive electric power source for small-scale usage in areas located away from utility lines. Whereas solar devices were only approximately 1 percent efficient back in the late 1800s, they evolved to being approximately 24 percent efficient in 2000, and are today approximately 25 percent more efficient than they were 10 years ago.

Similar to solar energy pioneers, innovators of piezoelectric flooring and vehicular thoroughfares bear the challenging task of convincing skeptics that piezoelectric energy as well as piezoelectric flooring and vehicular thoroughfares themselves are more than a curiosity. People living in society today expect to see immediate, tangible results and a proven track record before putting their trust into the visionary concepts of pioneers in modern piezoelectrics. Just as solar power was discovered over a century ago, so was piezoelectricity. Like solar power years ago, piezoelectrics is a non-mature technology. Consequently, high-tech piezoelectric devices lack a long test history. Also, reminiscent of solar power devices during their developmental stages, certain piezoelectric devices are not yet highly efficient, particularly with respect to the flooring products. For this reason, the price of materials and up-front initial investment relative to these products' energy output may make these products seem cost prohibitive and not economically feasible at this time.

Also similar to solar power, there are many positive attributes associated with piezoelectric devices. Like solar power, piezoelectric flooring and vehicular thoroughfares derive their power from reliable, replenishable energy sources. They can also be

installed in urban settings, where they preserve the established environment in its original state, do not occupy any additional public space, and do not contribute additional pollutants to the atmosphere as they generate power. Because of the world's continuing energy demands, these considerations should weigh favorably, given the waning supply, pollution and carbon emissions potential, and ever-increasing price of oil, natural gas, and coal. Moreover, while state-of-the-art developments in piezoelectrics may not have garnered the attention of the general public or scientists years ago, the expanded global interest by researchers in developing and testing piezoelectric technology is reminiscent of the heightened scientific interest in developing solar cells that occurred in the 1950's. If the level of pooled scientific interest and fervor to make piezoelectric flooring and vehicular thoroughfares more efficient is analogous to that for solar cells during its Bell Laboratories phase and thereafter, then potentially we should hope to see in the near future a burst of scientific breakthroughs in improved efficiency, lower materials cost, and commercial accessibility for these inventions. In support of this proposition, even with the refinements it is making to its vehicular thoroughfare products currently, Innowattech estimates that its current roadway, railway, and runway products will generate a return on a customer's initial investment over short a payback period of six to 12 years, depending on the traffic volume. Indeed, given the apparent mounting scientific interest in piezoelectrics, with the appropriate support from investors and strategic partners such as large energy firms and infrastructure managers, we may witness a push to deploy this technology within the next few years akin to that which solar power only experienced within the last few decades.

There are certain additional benefits to piezoelectric energy that other alternative energies, including solar power, currently do not offer. Certain geographic, topographic, and climatic factors are instrumental in determining where wind farms and solar cells are located. In contrast, because piezoelectric devices can be built into existing high traffic vehicular thoroughfares, these factors are inconsequential for determining the locations in which piezoelectric floors, roadways,

railways, and runways can be installed. Unlike wind and solar power whose energy capturing devices may be adversely impacted by severe, inclement weather, these piezoelectric devices can function in all weather conditions.

Implications for Opportunities to Structure and Invest in a New Breed of Asset-Backed Financial Products

The potential increased demand for piezoelectric projects could have profound investment banking implications in the future for investors and product structurers at investment banks alike. As piezoelectric flooring and vehicular thoroughfares become more economically efficient and feasible, more reliable, and more durable in terms of life expectancy, heightened demand for these products may potentially occur globally, resulting in increased mandates for large-scale piezoelectric projects. Presuming the international economic crisis improves from its current condition and institutional lending becomes prevalent once again, infrastructure loans, or commercial real estate loans, relating to the financing of large piezoelectric projects could be made. These loans could form the basis for formulating new fixed income piezoelectric project financial instruments, such as asset-backed bonds, that draw upon project finance practices, securitization methodologies, and other financing techniques for their structuring.

Three Hypothetical Scenarios, Taking Collateral Diversity into Account

The repayment scenario on the piezoelectric project loans would form the foundation on which the structuring of the currently hypothetical asset-backed bonds rest. The underlying loan obligations used to finance a large piezoelectric project have associated with them future income streams in the form of principal and interest payments to pay back the original borrowed debt. These receivables are due and payable in set intervals (monthly or quarterly, for instance) over a fixed period of time (generally, in years). Similar to other project financing endeavors, most of the financing for a large piezoelectric project would likely be repaid primarily from the income

stream generated by the expected cash flow and assets that the project itself generates.

There are several different ways the collateral structures supporting piezoelectric bonds could evolve, including the following hypothetical groupings: (1) the underlying loan obligations from the individual piezoelectric project, (2) the pooling of loan obligations from multiple piezoelectric projects, or (3) the pooling of loan obligations from one or more piezoelectric projects, together with the loan obligations from other types of financing projects, which could include other categories of renewable energy projects.

In the case of an individual piezoelectric project, the envisioned financing construct and its related securities could look as follows. Drawing upon securitization methodologies, the property right associated with the collection of the receivables for repayment of the loan to finance the piezoelectric project could undergo a “true sale” from the original owner of this right to a third party issuer. The issuer could then issue a new series of bonds in the form of asset-backed securities, with the income stream from the receivables associated with the repayment of the outstanding project loan serving as collateral, or, rather, “backing” these securities. This asset-backed series of securities need not have an extensive capital structure with multiple tranches holding different levels of seniority relative to one another. Rather, only one or two tranches of this new series could be issued, with the senior-most tranche being rated investment grade by two or more credit rating agencies, each of which the SEC has designated as a Nationally Recognized Statistical Ratings Organization (NRSRO or rating agency), such as Moody’s Investors Service, Inc. (Moody’s), Standard & Poor’s Ratings Services, a division of The McGraw-Hill Companies, Inc. (S&P), or Fitch, Inc. (Fitch). Even if these securities receive a non-triple-A investment grade rating, investors with a high risk tolerance may evaluate the risk-reward ratio for investment in such securities, and believe that they will be able to benefit from this investment in the long run. A downside of this hypothetical is that if a completed piezoelectric project does not perform as well as originally expected, it may be difficult for the outstanding loan on the project to be repaid, and the

loss severity to investors who purchased the asset-backed securities collateralized by the repayments of debt on this project could be significant.

This is why the proposed second case of having the debt from multiple piezoelectric projects pooled together may be more attractive. Generally, rating agencies look favorably upon collateral portfolios that are assembled with an eye toward collateral diversity. The thought is that the more diverse the collateral portfolio, the lower the cumulative probability of loss on such portfolio. The multiple piezoelectric projects case envisions a scenario in which the loan obligations from a group of piezoelectric projects are pooled together. These projects could be located either in the same country, or throughout multiple countries, presuming that similar loan underwriting standards are used for all loans in the portfolio, and that other risk factors are considered that relate to the likelihood of repayment of the debt for each of these projects (such as country risk, the project’s geographical location, size, expected traffic, etc.). Under this construct, for instance, loans from large piezoelectric projects in the United States, Israel, Japan, and elsewhere in the world could be pooled to form one integrated collateral pool.

The creation of such a diverse collateral pool could be advantageous insofar as it could spread the risk of repayment across multiple projects. This hypothetical situation could be preferable to one in which the risk of repayment is solely dependent and concentrated on a single piezoelectric project. Having multiple, diverse piezoelectric projects and the income streams on their related loan obligations in the collateral pool backing the vintage of asset-backed bonds issued could dilute the risk that could be associated with a poorly performing single project. Potentially, this type of collateral pool could provide sufficient support for asset-backed bonds with a more robust capital structure—one having multiple tranches of securities in several or more different levels of seniority relative to one another. Using a structuring methodology similar to that used in structuring cash collateralized debt obligations or securitizations, issuing multiple classes of subordinated securities, is a means of creating credit enhancement for the more senior tranches. Because

losses are absorbed in reverse order of tranche seniority, the most senior tranche in the capital structure benefits from this form of credit enhancement, as it is the last tranche to be affected by an interruption of cash flow from repayment of the underlying collateral loans. Generally, rating agencies assign ratings to different tranches in the capital structure based on each tranche's expected risk of loss due to its location and level of subordination in that capital structure. Having a multi-tranche capital structure could be beneficial for investors insofar as this structure could potentially increase the likelihood of having at least the senior-most tranche of securities be associated with a high probability of being able to pay scheduled distributions to holders of such securities, and having such securities receive a triple-A rating from the rating agencies.

To increase diversity and minimize default risk further, as the third case envisions, the collateral pool could be expanded to include other non-piezoelectric project debt, such as debt from other renewable-based projects, such as wind or solar projects, or debt from industries other than those in the energy field. Each industry group from which financial assets are originated is presumed to have zero correlation with other industry groups. Accordingly, the more diverse the collateral portfolio, the less risky the portfolio should be in terms cumulative defaults on the collateral securities backed by the receivables on this portfolio. Broadening the range of collateral pools into which piezoelectric loans could be inserted so that the loan from an individual piezoelectric project constitutes a relatively small percentage of the overall collateral portfolio could minimize the potential risk associated with this project, thereby making the bonds or other securities backed by this collateral pool have a lower degree of piezoelectric debt concentration risk than the case of bonds collateralized by an individual piezoelectric project or by multiple piezoelectric projects alone. Moreover, if such a collateral pool were managed by a collateral manager using techniques historically employed for managed, rather than static, collateralized loan obligation pools, then the sub-performing or non-performing loan obligations associated with a particular piezoelectric project could potentially be rotated out of the collateral pool at fixed intervals, and replacement financial assets that satisfy the eligibility criteria and other requirements could be

selected and inserted in its place in the collateral pool. Purchasing bonds backed by such a diverse collateral pool could be an option that certain investors who value diversity across multiple sectors may find attractive, depending on their level of risk tolerance.

As the above illustrates, new forms of asset-backed securities partially or fully collateralized by piezoelectric debt could be used as the basis for formulating novel fixed income securities or products, or could be integrated into existing, already established types of fixed income products. For those willing to invest in structured securities backed by piezoelectric debt, the risks may be high, but the benefits and rewards could potentially be great.

Rating Agencies and Issues Relating to Default Probability, Recovery Rate, and Default Correlation

Assigning ratings to bonds backed by piezoelectric projects may be something that rating agencies may be hesitant to do. This is because given the ultra-newness of piezoelectric projects, there is no performance history associated with these types of projects. This could be problematic for a number of reasons. First, rating agencies use the performance history of an asset type as a benchmark to predict future performance of similar assets. For instance, to estimate a portfolio's collateral quality under Moody's criteria, there are three main factors that drive the loss distribution of a collateralized debt obligation portfolio: default probability, recovery rate, and default correlation. Default probability relates to the likelihood of a tranche's inability to meet its debt payments and default, based on historical data of actual default experience for corporate debt. The default rates are calculated by rating category and by term to maturity, so that a direct relationship exists between the likelihood that a collateral security will default and its rating. Notably, S&P measures a tranche's credit quality primarily by using default probability. Absent a performance history, it will be difficult for rating agencies to estimate default probability for piezoelectric asset-backed bonds, and, consequently, it will be challenging for rating agencies to assign ratings to tranches of these bonds.

Arguably, bonds backed by piezoelectric project receivables as well as receivables from other projects and sectors could hold the most promise for purposes of obtaining a rating on bonds backed in part by piezoelectric projects. Although receivables on piezoelectric projects may lack an established history for purposes of default probability calculation, other receivables in such a portfolio may possess a more established and promising history. Also, the recovery rate represents the percentage of par value of the recovery amount on the defaulted asset. As a result, the recovery rate varies across industry sectors, asset type, and different periods of time. Because this percentage of recovery amount may be difficult to project relative to piezoelectric debt, calculating the recovery rate based on the other loans in the collateral portfolio may compensate for the absence of a piezoelectric recovery rate. Default correlation is one of the most difficult things to measure, as it measures the tendency of assets to default together. This means that for highly correlated collateral securities, if one obligor defaults, it is likely that similarly situated obligors in the same asset category will also default. Extrapolating this to highly correlated piezoelectric project loans, if one obligor defaults on such a loan, it is likely that similarly situated obligors will also default. When evaluating the risk profile of a loan portfolio, one therefore needs to understand both the default behavior of the individual collateral security as well as whether multiple assets in the same collateral portfolio are likely to default simultaneously. The pricing of each asset-backed tranche would take into account this correlation risk. Moreover, to address and minimize default correlation issues, concentration limitations are imposed on the collateral portfolio, so that only a capped maximum percentage of a certain type of financial asset—such as piezoelectric project loans - relative to the entire collateral pool itself, is permitted to be a collateral security. By limiting the concentration of piezoelectric project loans in a particular loan pool, rating agencies may be more likely to be less hesitant to assign ratings to asset-backed bonds that possess such loans as a collateral component.

Conclusion

Although piezoelectric flooring and vehicular thoroughfares have their share of critics, as a matter of

policy, these products are worthy of further public encouragement and support on a global scale. Like solar power years ago and many other evolving technologies, these piezoelectric devices may be novel, yet functional. Better yet, if the current research being conducted globally at prestigious universities continues to be encouraged and is supplemented through the efforts of outside investors and other strategic partners, these devices' product efficiency and ability to be rolled out for commercial use will likely improve within a relatively short time. Piezoelectric project finance transactions or other types of finance and technology endeavors could be available in the not too distant future, yielding opportunities around the world for investment bankers to draw upon established methodologies and techniques to create novel securities, and for savvy investors to potentially reap the rewards of these new financial products. Hopefully, policymakers and others will recognize the folly of Piezoelectric Pessimists' arguments, the value unique piezoelectric devices offer globally to the environment and the financial world, and the potential piezoelectric power holds as another promising alternative energy source worthy of continued public support and scientific development.

Kimberly E. Diamond is a vice chair of the American Bar Association's Carbon and Energy Trading and Finance Committee. She may be reached at kimberlydiamond@hotmail.com.

NR&E AVAILABLE ONLINE!

Natural Resources & Environment online contains all articles found in the paper copy, created in .pdf format. As a Section member, you have access to view *NR&E* after logging onto the Section Web site with your ABA Member ID number and password.

www.abanet.org/enviro/