



**THE PROGRAM ON ENERGY AND SUSTAINABLE DEVELOPMENT**  
*at Stanford University's Freeman Spogli Institute for International Studies,*

*<http://pesd.stanford.edu>*

**RESEARCH PLAN**  
JULY 2008

By many measures, the world's energy system is not keeping pace with the goals of sustainable development. Nearly one-third of the world's population still depends on traditional fuels such as dung to survive. Even in the advanced industrialized countries, where access to electricity and other modern energy systems is nearly universal, it is proving difficult to square the growing demand for energy services with other objectives such as averting dangerous changes in climate.

The Program on Energy and Sustainable Development (PESD) is an international, interdisciplinary program that draws on the fields of political science, law and economics to investigate how the production and consumption of energy affect human welfare and environmental quality.

Based at Stanford since 2001 with a core group of more than a dozen scholars including five senior Stanford faculty, the Program has built a worldwide network of more than fifteen international research institutes sponsoring four dozen scholars that collaborate on large, integrated studies. Much of the Program's research is based on detailed knowledge of the energy systems in the rapidly emerging markets of Brazil, China, India, Mexico and South Africa. In addition to sponsoring world class research, the Program leads advanced graduate and undergraduate courses and field seminars in energy policy at Stanford. The Program's core sponsors are BP, plc, and the Electric Power Research Institute (EPRI), a consortium that includes much of the world's electric power industry. In the coming years, PESD will expand to attract 2-4 additional major sponsors in finance, mining, equipment supply and related energy fields.

This note summarizes what the Program has studied in the recent past as well as its current major research topics. At any given moment the Program has 3-4 major studies under way.

## RECENT RESEARCH

### **Power Market Reform in the Developing World**

The Program has finished two major studies on power sector reform. First, PESD has examined the real experience with the wave of market-inspired reforms that has spread to most of the world's largest electric power markets. Early in 2007 the Program released a large study (published by Cambridge University Press) that compared the experiences with power sector reform in Brazil, China, Mexico, India and South Africa. The analysis, based on detailed casework by local experts in each market, explained why all these countries have faltered in their attempts to restructure their power markets and why the "standard model" for power sector reform, pushed by consultants and aid agencies such as the World Bank, was never likely to yield success.

PESD's study showed that successful power market reform hinges on a wide array of reforms outside the power sector—such as judicial reforms that empower regulators to make credible decisions and, crucially, financial reforms that force incumbent power generators to pay the real cost of capital and be subject to "hard" budget constraints. Absent such reforms, the private investors whose entry is essential to a competitive market remain especially wary that power markets will not operate on a level playing field. PESD also found that the most successful firms in these partially restructured power markets are "dual firms"—that is, companies that are able to combine the political assets needed to site plants, secure fuel supplies and negotiate favored contracts with the good management needed to ensure that profits are not squandered on political projects. We showed that "dual firms" require governance systems that are often difficult for traditional private investors to understand because they are focused on objectives that are distinct from traditional maximization of shareholder value. We also showed that the most successful "dual firms" are very difficult to unseat once they have occupied a dominant position in the market.

Second, PESD has published the most comprehensive assessment of the experience with independent power producers (IPPs) in the developing world. In a carefully controlled study, the PESD team—working with collaborators worldwide—examined the experience in 13 countries. The PESD analysis, which includes country studies that are regularly the most downloaded reports on our institute's website, has shown that formal contracts often fail and successful companies are based on strategies that protect their investments even when formal contractual terms don't hold. Strategies that rely on legal enforcement—including offshore arbitration—are much less successful than widely thought because arbitration is cumbersome and slow. The PESD analysis shows that in some cases, outside institutions such as multilateral development banks

have played a critical role in making contracts more stable and enforceable. Looking to the future, we conclude that IPPs are likely to play a niche role in most countries because these larger contractual problems have proven so difficult to resolve.

## **The Emerging Global Gas Market**

Most projections envision that global consumption of natural gas will nearly double by 2030. Gas is valued for its cleanliness and flexibility in industrial processes and residential heating as well as, increasingly, a rival to coal for generating electric power. However, in regions of highest expected gas demand growth—including North America, Europe, and South and East Asia—domestic gas production is proving unable to meet projected consumption needs. Tight gas markets have driven prices to all-time highs, making it harder for gas to compete.

Plentiful, low-cost gas reserves do exist—most notably in Russia, Africa and the Middle East. The viability of gas as fuel for growing world economies critically depends on massive investments in pipelines and liquefied natural gas (LNG) supply chains to move gas from fields to markets. Economics strongly support the necessary investments in inter-regional gas transport networks. Politics—both interstate and internal risks to private investment—has long been and will continue to be the key constraint on investment in new production and transit infrastructures.

PESD has examined this emerging global market for gas in three ways. First, we have released the study “Natural Gas and Geopolitics” that looks over the last three decades and over a similar horizon into the future at the structure of the world’s gas market. The study has sold heavily, was the subject of a keynote presentation at the 23<sup>rd</sup> World Gas Conference in June 2006 (the largest and most important gathering of the gas industry) and has been referenced at numerous other high-level meetings, in op-eds and by press in the major news outlets. Among our key findings is the conclusion that a “gas OPEC” is unlikely to be effective because the gas industry is much more dependent on infrastructure and price-sensitive markets than oil—those factors favor investment in countries and settings where a cartel is especially difficult to form. We also show that investors in gas projects are much more sensitive to the quality of the host government, which raises the prospect that much—perhaps most—of the world’s gas will be left in the ground because the governance systems above ground are not conducive to investment. We have found that already about half of the world’s gas reserves are “dead”—in effect, unavailable to the market—for that reason.

Second, PESD supported a Ph.D. thesis that modeled monthly transatlantic LNG flows. The model shows how differences in the cost of storage across the Atlantic have a large effect on flows since LNG, in practice, allows investors to source storage services in the market where they are least costly. We have also modeled the “option value” of regasification and quantified, in light of the volatilities that are typical of the US and European markets, the benefit for LNG suppliers to hold large portfolios of regasification terminals in both markets.

Third, PESD released studies of demand for gas in China and India – two potentially large but poorly understood energy markets. Our analyses focused on the market competitiveness of natural gas against other fuels, especially coal. Collaborating with six research teams—three in China and three in India—we found that gas is unlikely to compete with coal for power generation except where local environmental rules are extremely stringent or where local power consumers are generating their own electricity because grid service is unreliable. In many cases, industrial consumers offer the most attractive economics for a switch to gas under a tight pollution control regime. Conversely, policies not directly focused on the environment—such as reforms in the coal sector or financial sector rules affecting relative costs of capital—can have powerful implications for local pollution and climate change by altering the relative economics of coal and gas. These results suggest that efforts to address climate change may need to consider these other potent levers beyond traditional environmental policy.

## **MAJOR STUDIES UNDER WAY**

### **Climate Change Policy**

The record of the Kyoto Protocol, the world’s first substantive treaty to regulate the emissions of gases that cause global warming, is mixed. In some countries, notably in Europe, Kyoto has framed extensive efforts to limit emissions, although even in Europe most nations are struggling to meet their commitments. Other countries, notably the United States, remain outside the Kyoto Protocol. Developing countries have joined the Kyoto Protocol in large numbers because they are exempt from any emission controls, and the Protocol’s Clean Development Mechanism (CDM) has offered the promise of new investment. Even if all nations met their Kyoto commitments the impact on global warming would be small, for the Kyoto Protocol expires in 2012 and real solutions to the climate problem require a sustained effort for many decades beyond.

PESD’s research is looking beyond the Kyoto Protocol and will produce a series of articles and other major publications that outline a more effective “post-Kyoto” vision for managing global warming. This work rests on several pillars. First, we have found that “cap and trade” systems intended to control emissions rely heavily on institutions to monitor and enforce emission credits. Because those institutions exist only at the national and regional level, these cap and trade systems are likely to remain highly decentralized and to emerge into a global system only slowly and from the “bottom up.”

Second, we have found that the major mechanism for engaging developing countries—the CDM—is largely failed. In practice, the CDM has mainly attracted investment in minor emissions control activities, and many CDM projects are of dubious quality. Worse, the CDM creates incentives for developing countries to inflate baselines and to remain disengaged from meaningful limits on greenhouse gas emissions. PESD has documented the troubles with CDM in several high profile publications and is now outlining a new strategy for engaging developing countries. Our work is looking at a

different approach that would focus on investments in new energy infrastructure. The goal is to identify investments that align with developing countries' interests while also cutting emissions of greenhouse gases. Preliminary work by PESD has shown that such schemes—for example, encouraging the construction of a natural gas pipeline network in China, which would lead to the greater use of more carbon-frugal gas instead of carbon-heavy coal—would lead to much greater leverage on emissions than current approaches, such as the CDM. In Guangdong province, alone, tighter air pollution controls could lead to savings of about 100 million tons per year of CO<sub>2</sub> through more extensive investment in gas-fired power plants instead of coal-based technologies. PESD is now crafting these insights into a more general strategy for forging deals with essential developing countries.

Third, PESD has been outlining international legal strategies more effective than the binding Convention-Protocol system that has dominated most of the post-Kyoto negotiations. Alternative strategies could make fuller use of ambitious, flexible and non-binding commitments in the G8+5. PESD's research is exploring how these smaller forums allow for more meaningful commitments and also is identifying the institutional back-up that will be needed for enforcement.

Fourth, PESD is identifying sources of major policy failures around climate change and is determining strategies for overcoming them. These failures include the severe under-investment in research and development of new technology as well as poor investment in energy efficiency.

### **National Oil Companies**

Another major study under way at PESD focuses on the organization of the world oil market. Even as governments shift control over most economic activities to private firms and markets, a quite different pattern prevails in the supply of hydrocarbons. State-controlled oil companies—so-called “national oil companies” (NOCs)—remain firmly in control over the vast majority of the world's hydrocarbon resources. And so long as energy prices remain high, the central role for NOCs seems more secure than ever. Governments are struggling to find the right policies toward their NOCs. The NOCs are rethinking their roles in the future world hydrocarbon industry.

PESD's work is studying fifteen of the world's most important NOCs, with the goal of understanding the factors that determine their performance and business strategies. The sample includes all the major enterprises in the Persian Gulf and Latin America as well as a sample in Africa and Asia. It includes companies that concentrate on producing oil and gas as well as those with large refining and final marketing operations. (A first set of case studies—including PDVSA, Pemex, and Gazprom—has already been completed; through the remainder of 2008 and first half of 2009 we expect to bring the balance of the cases to a conclusion.)

PESD's results show that NOCs are actually much less dominant than is often thought. Many of them preside over large amounts of “dead” oil and gas—resources that

are in the ground but not accessible to the market. While this form of industrial organization is generally not efficient, the central presence of NOCs is not surprising when viewed from the vantage point of history and the difficulties that host governments have had in controlling firms on their territory. NOCs are but the most recent installment in a long-standing effort by governments to maximize the appropriation of earnings from their endowment of natural resources. Governments created NOCs, in part, because they thought that NOCs would be more pliable “agents” for the state’s goals. In reality, in most cases NOCs have become their own “states within a state.” PESD’s research is exploring how these NOCs gain their autonomy and the strategies that governments have used to try to regain control—such as through control over senior appointments and budgets. PESD’s work also suggests that when costs rise and prices ease, NOCs will find themselves quite squeezed and prone to reform initiatives that are likely to make them look much more like IOCs—partly by weakening the grip of governments on the investment and operational decisions of NOCs.

PESD’s research is also revealing that NOCs are not the unproductive, isolated and nationalistic monoliths that are often assumed. Rather, there is a wide variation in their performance and in their strategy toward investment and industrial organization, including partnerships with outside firms. The sources of the variation in performance and strategy are many, and some are intrinsic to the geological nature of the resources, but government policy also can have a large influence. Our studies suggest that the most important policies relate to control over the NOC’s budget and allocation of capital.

## **The Global Coal Market**

Despite its environmental shortcomings, coal has been the fastest growing major fuel globally over the past five years. PESD is interested in identifying the drivers of this growth, and, in an era of potential carbon constraints in many markets, whether we should expect this growth to continue. We recently initiated a study of the global coal market that looks at three interlocking factors. First, it examines whether (and how) the regionally heterogeneous coal trade will link to form a truly global market—much as LNG trading, with time and innovation, has created a global market for gas. Second, it explores how regulatory reforms in key coal consuming and producing states—notably the large consumers of China and India—could accelerate the shift to globally sourced coal, and its impact on local coal prices. Third, it considers what business models (and supporting regulatory frameworks) could facilitate the rollout at scale of carbon capture and storage (CCS)—a critical enabling technology for coal use in a carbon-constrained world. All three of these elements will allow PESD to apply a much more sophisticated story about the future for coal to its work on climate change as well as its studies on the energy systems of China, India and other emerging markets.

The study will be structured in accordance with the three substantive elements described above. PESD’s collaborators in DIW Berlin are developing a model of the global coal trade through 2030 to answer broad questions about the structure and dynamics of the global market: how are prices formed, can suppliers exert market power, what is the role of swing producers and arbitrage in linking together regional markets,

and how would global coal use patterns change in the presence of major carbon constraints. Country-level analyses of major coal producers and consumers will provide key inputs to the model and also independent insight into drivers and patterns of coal sector reform. While coal is a widely distributed resource, from a global perspective only a few countries have much leverage on the market. China, India, the U.S., Russia, South Africa, Australia and Indonesia account for 80% of world production of coal. Of the states that do not produce significant amounts of coal, only a few (France, Japan, Taiwan) are significant consumers. This means that we can analyze the vast majority of the global coal market by examining a limited number of countries in detail.

In a world where the central role of coal for power generation is unlikely to diminish in the near term, rapid development of CCS technology is crucial for mitigating carbon emissions from coal. And yet so far only niche applications of CCS are seen at scale—none associated with large-scale power generation from coal—and the regulatory environment that would stimulate development of a full-fledged carbon storage industry is almost totally lacking. Our research considers the possible business models which could make storage projects economically viable, both in the current conditions of regulation and capital cost as well as under other possible scenarios. Characterizing business models for an industry whose projects are so far mostly “vaporware” requires several complementary approaches. First, we are studying the historical development of analog industries which share some of the salient characteristics of CCS: high capital intensity, technologies unproven at scale, complex value chains, and, critically, a commodity (in this case CO<sub>2</sub>) whose primary value derives from regulation. Second, we are initiating case studies of a representative sample of carbon storage projects which are furthest along. Some of the projects considered are operating, others remain under development, and still others are foundering or have been cancelled—we seek to understand how the different business models have shaped outcomes in each case. Third, because the sample of projects at an advanced stage of development is limited and not necessarily representative of a future carbon storage industry at scale, we are interviewing key players in the CCS space—industry actors, policymakers, regulators, and academics—to plug holes in our understanding and construct a broader vision of how the industry is likely to evolve.

## **Energy and Development**

Since its inception, PESD has sponsored a wide array of studies aimed at improving the understanding of how modern energy services contribute to human development. These studies have included data collection and reports in Brazil, China, India, and South Africa, support for several doctoral theses in the area, and analysis of particular policies that countries have adopted. For example, working with our collaborators at the University of Cape Town, PESD has shown that South Africa’s policy of providing free electricity to households is dramatically more costly than necessary. Using survey data we showed that households are using this electricity for cooking, which in turn is eroding the reserve margin on South Africa’s already fragile power grid. A better policy would give low-income households “clean energy credits”

that they could use to purchase any number of energy sources—including LPG and solar home systems that are less costly ways to cook and heat water.

Most of PESD’s research in this area has focused on the “business model” for electrification. Working with the University of British Columbia, PESD has compared the experiences with 21 different business models—from philanthropic programs to hard-nosed for-profit systems—in Brazil, Cambodia and China. The study, in draft, finds that purely philanthropic systems often fail because they are not scalable and, at times, drive productive for-profit systems out of business. Our findings are a warning to western companies and NGOs that have sought to help the world by subsidizing energy supplies that, in practice, their programs may actually cause more harm than good. We have also shown ways that subsidized programs can be designed so that the subsidy does not crowd out productive investment. Engaging for-profit enterprises, including business, will be essential to energizing the whole world.

Accordingly, our newest research on energy and development follows efforts by businesses to provide energy services to the very poor at a profit, seeking to identify the causal factors that determine the success or failure of such initiatives and also to track the social welfare outcomes that result. Our initial work focuses on for-profit implementations of biomass gasifiers for rural electrification in India. In concert with our study of the trajectories and outcomes of the energy projects themselves, we are examining the rural biomass markets that must feed the gasifiers, with the goal of understanding the subtle ways that demand for biomass for energy can positively or negatively perturb local economies, land use patterns, and social outcomes.