“Leveraging Public-Private Partnerships for the Indian and Global Environment” (Grant Ref. AID-OAA-G-12-00007)

Implementation Plan submitted to USAID-DIV

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1. Introduction

This document is the implementation plan for J-PAL South Asia’s project titled “Leveraging Public-Private Partnerships for the Indian and Global Environment” – a randomized evaluation of energy-efficiency measures in Indian industrial plants, funded in part by USAID under the grant AID-OAA-G-12-00007.

The project is a campaign to reduce greenhouse-gas emissions by increasing the efficiency of energy usage at Small- and Medium-Enterprises (SMEs). Many firms fail to undertake energy-efficiency investments that engineering studies show are positive in net present value. By providing Detailed Energy Audits and follow-on technical assistance, the campaign will close this “energy-efficiency gap" between the low observed efficiency of SMEs and their technical potential. Inducing firms to undertake energy-efficiency investments may be a win-win if it saves firms money while reducing greenhouse gas emissions. By conducting energy audit and energy manager interventions as a randomized-controlled trial, the project will accurately measure the returns to investment in energy-efficiency, relative to a control group of firms not induced to adopt energy-saving measures.

The sections below detail the project design and the implementation plan for the components of the treatment and the endline survey. Section 2 presents the research design and describes the nature of the treatments. Section 3 describes the consultants contracted to carry out these treatments and Section 4 the sample of plants participating in the study. Section 5 discusses the design of the endline survey of technology adoption and energy use. Section 6 summarizes by describing the timeline of these project activities.

2. Research Design

The project is a randomized-controlled trial design to measure the returns to industrial energy-efficiency measures. Two different treatment arms, detailed energy audits and energy managers, are designed to test the leading hypotheses for why many firms do not adopt energy-efficient technologies. After the conclusion of these interventions, the firms will be surveyed in order to measure the impact of the treatments on their technology adoption and energy use.

The interventions are:

I. *Detailed Energy Audits.* A detailed energy audit is an analysis of plant process and utility systems to identify areas where the plant might profitably save energy. The energy audit consists of a 2-5 day on-site component to understand the plant process and take measurements and an off-site analysis component to synthesize the data from the audit and make recommendations on measures that the plant could adopt. The audits cover the use of both thermal and electrical energy. On the thermal side, the scope includes boiler efficiency and steam distribution and utilization. On the electrical side, audits cover motors, pumps and other electrical equipment, lighting and the plant electrical distribution systems. The audit report presents measures the plant could adopt in each of these areas along with their projected economic return.

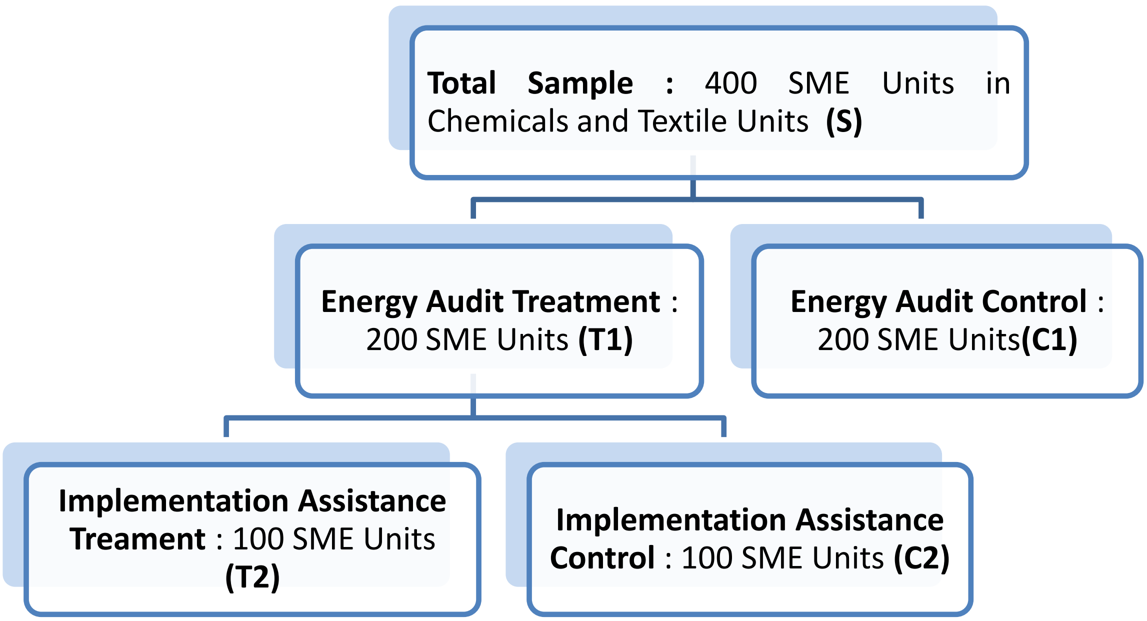
   The motivation for energy audits as an intervention is the pervasive hypothesis that informational market failures may prevent the adoption of efficient technology. These failures could take two forms. First, asymmetric information between firms and service providers may deter adoption of efficient technologies. If firms are not able to independently evaluate the returns on energy-efficiency investments, energy consultants may oversell their services and drive wary firms to shade their expectation of returns or drop out of the market (DeCanio and Watkins, 1998; Howarth et al., 2000). Second, information about efficiency may be undersupplied in the market because it is a public good. A plant discovering, testing or disseminating a technology in its industry can benefit competitors by providing an example. Because plants do not take this common benefit into account, there will be too little information about efficiency supplied by the market (Anderson & Newell, 2004).

II. *Energy Managers.* The energy manager intervention provides skilled technical assistance to help plants implement the recommendations from audits. The energy managers assigned will spend a total of 15 days at the plant over the course of 3 months to supervise the selection, procurement and installation of new equipment, verify savings from audit measures and train plant staff.

   The motivation for energy managers as an intervention is to test the relation between skilled labor and technology adoption. A leading alternative to informational hypotheses is that efficient technology is complementary to other productive factors, especially skilled labor. Small plants relying on unskilled labor may therefore rationally choose to be less efficient—there is no use adopting sophisticated process controls that plant staff cannot operate. In this view, engineering estimates of technology savings miss the hidden costs of complementary productive inputs.

The structure of the experimental treatment groups has been summarized in Figure 1 below. Of the total sample of roughly 400 textile and chemical plants, 200 are randomly assigned to the detailed energy audit treatment, stratified on the baseline variables of fuel and electricity bills. Amongst the 200 firms in the energy audit treatment, a further half (100) are assigned to receive energy managers for implementation assistance. This random assignment is stratified on both electricity bills and the projected returns to energy-efficiency for each plant projected in the energy audit.

Figure 1: Experimental Design



The primary outcomes for the study are energy use and technology adoption. Because the treatment and control group are randomly selected from a common population, these outcomes will be statistically comparable when the project starts and any differences between the treatment groups will be causally attributable to the treatments themselves.

The main difficulty in measuring returns to energy-efficiency is that the plants that adopt such technology will not be representative of all other plants. Adopters will generally have adopted because they expected higher returns than non-adopters. The design addresses this problem by stratifying the randomization for the energy manager intervention on the projected returns to energy-saving within the energy-audit group. The energy managers will then work to implement recommendations, both in plants where efficiency appears to have high returns and where it appears to have low returns, so that the study may observe returns even for relatively low-return plants that normally would not consider adoption. The design will thus map out the relationship between projected and achieved energy savings.

3. Industry Selection and Characteristics

India has more than three million SMEs, many of which are extremely energy-intensive relative to other plants in the same sectors. The state of Gujarat alone contains tens of thousands of industrial units, spread across the state in clusters organised by Gujarat Industrial Development Corporation (GIDC) and Gujarat State Financial Corporation (GSFC). In total, there are 83 SME clusters in Gujarat in diverse industries like Textiles, Machinery, Food Products, Chemicals, etc. We focus on the textiles and chemicals industries as these both are important for the Indian economy and use energy in many ways. Textiles and chemicals are the first and second manufacturing sectors in the Indian economy by both output and employment. These industries use a lot of electrical energy as well as thermal energy, generated on-site from fuel combustion.

The chemical plants chosen as research subjects are located in the chemical industries' clusters in Vatva (Ahmedabad) and Ankleshwar (Bharuch), and textile process houses were chosen from Surat and Narol (Ahmedabad). J-PAL South Asia's program on energy efficiency for SME's has been supported by Green Environment Services Co. Ltd. (Vatva), Ankleshwar Industries Association (Ankleshwar) and South Gujarat Textile Processors Association (Surat) in their respective clusters in terms of encouraging member industries to participate in the project.

The project selects plants to participate in two stages, screening for interest and restricting by scale. We first selected chemical and textile processing firms from the industrial association directories contacted them to solicit interest in receiving the treatments free of charge. For plants that express interest, energy consultants conduct a brief baseline survey to collect information about energy demand, fuel consumption, annual sales and other characteristics. We screen these interested plants to keep only those with electrical contract demand (a measure of load) less than 500 kVA. This size limitation makes the scale of energy use in the sample more homogeneous, reducing the variance of energy use and making it more likely the project will detect changes due to the treatments.

To date the program has confirmed interest from 480 SMEs from Vatva, Narol, Ankleshwar and Surat, out of which 435 SMEs meeting the size restriction were selected for the sample. The plants selected have total investment in plant and machinery less than 50 million INR (i.e., $1.5 million) and consume a range of fuels from natural gas to coal, lignite and even wood. About 50% of total energy bills for these plants is in electrical energy and the rest fuel.

4. Consultant Selection

The treatments are being carried out by local energy consultants certified by the Bureau of Energy Efficiency (BEE), Govt. of India or the Gujarat Energy Development Agency (GEDA), Govt. of Gujarat. JPAL South Asia contacted these energy auditors at the start of the project. Each auditor submitted their letter of intent, past work description and the budget for Chemical and Textile Sectors – the clusters involved in the study. We evaluated the proposals based on technical expertise in conducting thermal and electrical audits, proposed audit costs and the experience of the Gujarat Energy Development Agency to shortlist seven consultants for the program. These are:

- Dalkia Energy Services Ltd., Ahmedabad
- Dev Engineers, Ahmedabad
- Dynamic Consultants, Ahmedabad
- Mitcon Consultancy, Ahmedabad
- Saket Projects, Ahmedabad
- Synergy Consultants, Mumbai
- Total Energy Consultants, Ahmedabad

J-PAL has conducted capacity building for these consultants in partnership with TERI (New Delhi) and Forbes Marshall (Pune) to assure a high quality of work in the treatments. We worked with these consultants to successfully complete a pilot phase before the full scale launch of the program. The pilot was carried out for 17 units located in Vatva, Ahmedabad and was intended to test the survey instrument and streamline the audit procedure across various consultants. The observations from the pilot program helped us to create an exhaustive list of energy saving measures for different processes prevalent in chemical and textile sector SMEs, which was shared with the consultants in order to bridge information gaps.

The detailed energy audit and energy manager work is allocated to consultants in waves. In each wave, the plant to be assigned are randomly allocated to each consultant in proportion to their capacity. This enables us to monitor the quality of work across consultants reliably without the comparisons being confounded by plant characteristics.

5. Endline Survey

The main outcomes of the study are technology adoption and energy use. These outcomes will be measured in a uniform endline survey across all 400 sample plants. The survey will both interview plant owners / managers and collect detailed technical information on plant efficiency with direct measurements. The survey will be supervised by J-PAL South Asia Research Associates and field monitors and technical data collected by The Energy and Resources Institute (TERI), New Delhi.

Technology adoption will be measured both through surveys and through direct observation in plants. Investments in new equipment or upgrades in the production process will be recorded through direct interviews with plant managers. This survey data will record what upgrades plants made and what those changes cost. These investments will be physically verified through equipment inventories and intensive field measurements of efficiency. The survey prioritizes equipments that use a large amount of energy or are likely to have been upgraded after energy audits for detailed measurement. The survey team will then measure the efficiency of two fuel-consuming equipments (e.g. boiler, furnace, thermic fluid heater) and four electricity-consuming equipments (motors, pumps, compressors etc.). The combination of both financial and technical data on these upgrades will allow accurate measurement of investment returns.

The endline survey will also measure energy use in aggregate by collecting fuel and electricity bills. The survey team will collect energy bills from the prior 18 months. The survey will cover a range of plant characteristics, financial information and production data in addition to these primary outcomes.

Two teams from TERI will work simultaneously during the endline survey, each team completing surveys at the rate of two industries per day. JPAL field monitors will accompany each survey team to record non- technical data while the TERI engineers will collect field measurements. The survey has been piloted to gauge its length in practice and the sufficiency of measurement methods for equipment efficiency. The pilot was successful in getting consistent cooperation from sample plants and collecting a wide range of technical and economic measurements in a brief time. We have further refined the survey instrument based on the pilot results.

As aggregate energy use is a critically important outcome, and one that we will want to continue to track after the endline survey, we are in the process of signing agreements with power utilities to provide the electricity bills of the plants in the sample for a period of two years during and after the experiment.

6. Timing of Project Activities

The project activities would be executed as per the plan listed in the table below. The numbers given in Energy Consultancy Site Visits and Energy Manager Intervention columns should be read as "Assigned / Complete". The J-PAL team in Ahmedabad has obtained consent letters from the industries for their enrolment in this program, and assigned 73 units amongst the consultants for field audits in the month of January, in two separate waves, one each in the first and last week of January. We expect the first batch of audit reports to be submitted to J-PAL in February, following which, after required data analysis, some of them (approx. half) would be re-assigned for technical assistance through an Energy Manager. The technical assistance process would be held over a period of 3 months.

The field audit activities in 100 industries are expected to be complete by first week of May. The first batch of technical assistance process would be complete by the same time, which would be followed by the Endline Survey in those units along with corresponding units in the control sample. The figures in the Endline Survey column are cumulative, with approximately 15 surveys planned per week, and two teams from TERI would be deployed simultaneously, with J-PAL's assistance.

The technical assistance process and Endline Surveys are expected to be completed in the field by the last week of July. We will then have sufficient time to enter and clean this data for the presentation of preliminary results at the final milestone in September.

Month	Date	No. Of Energy Consultancy Site Visits Assigned / Complete	No. Of Energy Manager Intervention Assigned / Complete	No. Of Site Field Surveys Complete (cumulative)	US AID Milestones	Roles and Responsibilities
Jan '12	2	30 / 0			**Milestone 1**: Implementation Plan (Feb '12)	• J-PAL assigns units to Energy Consultants for audits • Consultants establish contact with assigned units, fix appointments and conduct site work • Consultants send audit reports to J-PAL • J-PAL scrutinizes the data in audit reports
	9					
	16					
	23					
	30	73 / 0				
Feb '12	6					• J-PAL receives the final audit reports • J-PAL analyses audit data and assigns units for technical assistance • Consultants approach the units with implementation proposal • J-PAL monitors technical assistance execution
	13					
	20	73 / 30	15 / 0			
	27					
Mar '12	5	100 / 30				• Audit assignments, field work and technical assistance work to continue • Milestone 2 Complete with 50 audits
	12				**Milestone 2**: 50 Field Audits Complete (Mar '12)	
	19	100 / 73	37 / 0			
	26					
April '12	2					• Audit assignments, field work and technical assistance work to continue
	9					
	16					
	23					
	30					
May '12	7	100 / 100	50 / 15	15		• J-PAL receives the final reports of technical assistance assignment • Site field surveys to be conducted jointly by J-PAL and TERI
	14			30		
	21					
	28					
Jun '12	4		50 / 37	45		• Field audit work, technical assistance and Site surveys to continue • Milestone 3 Complete with 100 audits and 50 Surveys
	11			60	**Milestone 3** : 100 Field Audits, 50 Field Site Surveys (Jun '12)	
	18			74		
	25					
Jul '12	2					• Milestone 4 complete with 100 audits and 100 site surveys • Technical assistance complete in 50 units
	9					
	16				**Milestone 4** : 100 Field Audits, 100 Field Site Surveys (Sep '12)	
	23		50 / 50	89		
	30			100		

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Progress Report and Preliminary Scaling Plan
submitted to USAID-DIV

Nicholas Ryan
J-PAL South Asia at IFMR
April 15th, 2012

1. Introduction

This document is a joint progress report and preliminary scaling plan for J-PAL South Asia's project titled "Leveraging Public-Private Partnerships for the Indian and Global Environment" – a randomized evaluation of energy-efficiency measures in Indian industrial plants, funded in part by USAID under the grant AID-OAA-G-12-00007. Our previous communication on the same project was an implementation plan submitted February 13th, 2012.

The project is a campaign to reduce greenhouse-gas emissions by increasing the efficiency of energy usage at Small- and Medium-Enterprises (SMEs). Many firms fail to undertake energy-efficiency investments that engineering studies show are positive in net present value. By providing Detailed Energy Audits and follow-on technical assistance, the campaign will close this "energy-efficiency gap" between the low observed efficiency of SMEs and their technical potential. Inducing firms to undertake energy-efficiency investments may be a win-win if it saves firms money while reducing greenhouse gas emissions. By conducting energy audit and energy manager interventions as a randomized-controlled trial, the project will accurately measure the returns to investment in energy-efficiency, relative to a control group of firms not induced to adopt energy-saving measures.

The sections below are a status update on the work in the second milestone and a preliminary scaling plan. The progress report describes the field work to date and the scaling plan gives channels through which the project findings might be scaled up when the project concludes.

2. Progress Report: Baseline Survey Results and Energy Consultancy Work

This section describes the status of the project to date with respect to the milestone of:

- Baseline survey to include:
    - Average and variance in measures of energy use in 400 industrial plants and across audit innovations / schemes.
- 50 energy audit site visits completed.

Baseline Survey

The baseline survey has been completed for 425 units against a planned target of 400. The purpose of the baseline survey is primarily to solicit the interest of plants and to collect energy use data from plants. This energy use data provides a control that will make the estimates of the treatment impact more precise and allows the sample to be much smaller than would otherwise be necessary.

The study sample has been selected through a broader contacting phase that solicited interest in participating in the project from industrial plants. The results of this contacting phase to date are shown in Table 1. We have attempted to contact a total of over 1,039 plants. The tables shows the number of plants that consented to participate and, amongst those plants that did not consent, the reason why not. A total of 467 plants consented to participate in the program, well above the target sample of 400 units, and we have preliminary baseline survey data from all 467 of these units. Not all of these units, however, were suitable for the project, mostly due to being too large. Large units are costly to audit and, because they contribute disproportionately to average energy use in the sample, make the outcome measures much noisier. We have therefore set a cut-off on electricity contract demand to limit the sample to those units that are not too large.

Table 1: Plant Interest in Energy Audit

	Number	Percent
Interested	467	44.9
Not interested		
Already have consultant	55	5.29
Energy not a large cost	62	5.97
Scope of savings not large	85	8.18
Not operational	154	14.8
Other reason	216	20.8
Total	1039	100

This cut-off initially cut the sample to 397 interested units to date. Through intensive, personal revisits, we were able to gain interest from additional firms in Surat, Narol and Ankleshwar and have thus increased the sample to a total of 425 units of suitable size, well in excess of the planned target. The entire J-PAL Ahmedabad team contributed to this revisiting process, but

Maulik Chauhan deserves special praise for his enthusiasm and personal advocacy of the project's aims, which won over many sceptical plant owners.

Table 2 (on page 3) shows the characteristics of the study sample by treatment status using data from the baseline survey. The table, like the experiment, encompasses both technical and economic characteristics. All characteristics shown are balanced across the treatment and control groups of the experiment. The randomization was performed stratified on electricity and fuel bills, as these are the primary outcomes in the experiment and stratification will raise power to detect changes in these outcomes. Sample plants have an average contract demand right around 200 kVA. Contract demand is the plant's commitment with the power company to draw a certain amount of maximum load and is used by the power company to forecast total demand. The average sample plant employs a little more than 80 people, has about USD 0.5m of capital investment and USD 1.6m in sales. Energy is a large cost for these plants. The average plant spends around USD 200,000 on electricity and fuel in a year, or around 12.5% of sales on average, which may be around 15-20% of total costs. The balance between electricity and fuel bills is about equal, and the fuel bill is further divided across a range of fuels, from relatively dirty and inexpensive lignite to coal, diesel and natural gas.

Figures 1 and 2 (on page 4) plot energy use against annual sales for Chemical and Textile plants, respectively, in the study sample. These figures show two striking facts. First, at any given level of sales and within a given sector, there is an enormous variation in the range of energy that a plant uses. The energy-efficiency of plants varies by a factor of threefold or more. Second, looking across sales levels for plants, energy use increases only gradually with plant size. The quadratic curve of best fit within sector has a gentle upward slope that flattens out within the sample. These facts suggest that many plants certainly are short of the technical frontier of production in their sectors, and are consistent with nationally representative manufacturing data from the same sectors. This experiment will test whether this technical variation in energy-efficiency actually corresponds to missed investment opportunities on behalf of inefficient plants, or is due to other, unobserved factors that affect plant decision-making and are correlated with energy use.

Table 2: Sample Characteristics by Treatment Status

	Sample mean [sd]		
	Treatment	Control	Difference
Contract demand (kVA)	201.3	188.8	12.5
	[173.1]	[170.3]	(16.7)
Electricity bill (Annual USD 000s)	85.9	82.8	3.14
	[110.6]	[106.2]	(10.5)
Fuel bill (Annual USD 000s)	110.7	114.5	-3.88
	[431.4]	[275.4]	(35.2)
Employees	83.2	80.0	3.13
	[112.8]	[115.5]	(11.2)
Capital (USD 000s)	519.7	571.1	-51.5
	[743.9]	[817.0]	(82.1)
Sales (USD 000s)	1628.5	1776.1	-147.5
	[2336.9]	[3754.7]	(319.9)
Uses lignite (=1)	0.29	0.32	-0.023
	[0.46]	[0.47]	(0.045)
Uses coal (=1)	0.23	0.19	0.039
	[0.42]	[0.39]	(0.040)
Uses diesel oil (=1)	0.11	0.16	-0.054
	[0.31]	[0.37]	(0.033)
Uses gas (=1)	0.46	0.55	-0.092
	[0.50]	[0.50]	(0.048)
Observations	214	211	

Figure 1: Energy Use Against Sales, Chemical Plants

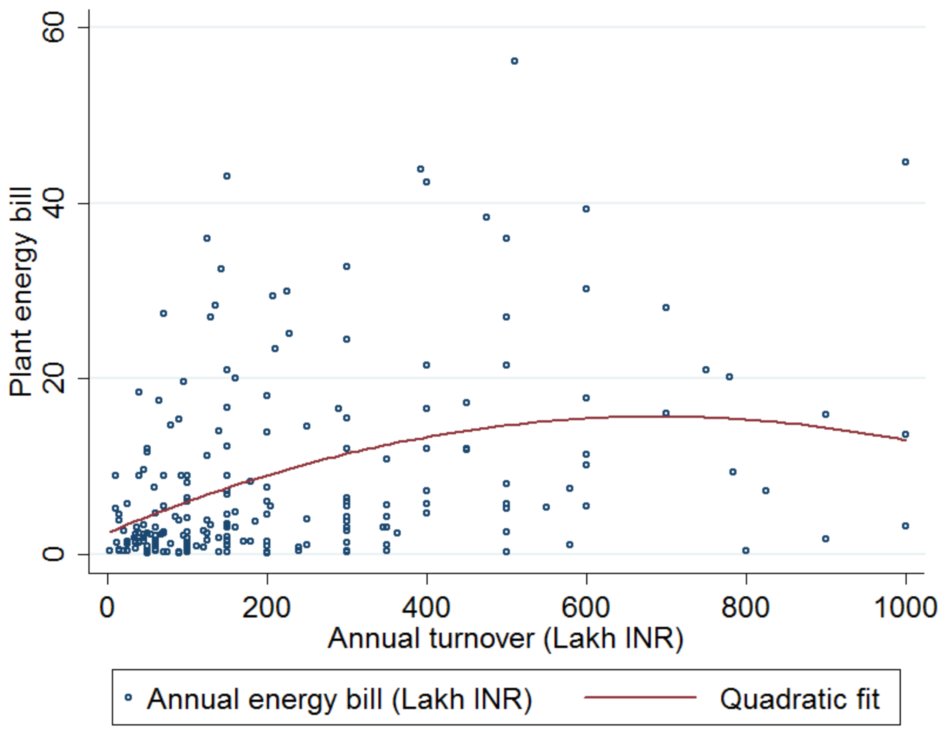
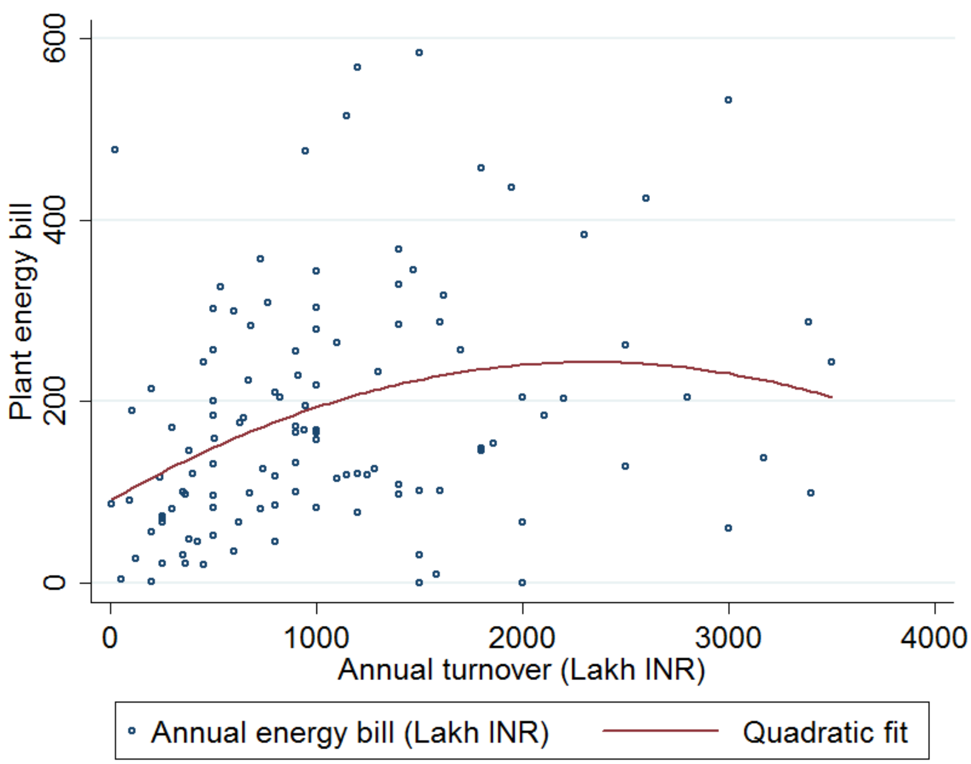


Figure 2: Energy Use Against Sales, Textile Plants



Energy Audit Site Visits

The energy audit work for the project is well under way, with 60 of the audits funded by USAID either pending or completed, in excess of the target of 50 for the first milestone. An energy audit consists of about 5-7 days of field work, several days of subsequent analysis, an initial comment by JPAL staff on a preliminary draft and then the receipt of a final audit report and presentation to units and to J-PAL SA. We have received final, completed audit reports for 29 audits in this wave and a further 31 audits are pending in the field, with field work started but the final report not yet received.

The energy audit work is back on the schedule as laid out in the implementation plan after falling somewhat behind. We have assigned energy consultants to interested plants for the full scope of field audit activities, 100 plants in total, and expect this work to be completed in full by the end of May. Cooperation from the participating industrial associations has been crucial to the design and implementation of the project to date. The energy audits funded by USAID have been assigned in the Surat, Ankleshwar and Narol industrial areas. Assignment is the first stage of energy audit work when JPAL informs energy consultants of a set of plants they will be auditing next. Ankleshwar primarily has Chemical factories whereas Surat and Narol have Textile factories.   The DIV grant is being used to expand the energy audit samples in each of these areas.

3. Preliminary Scaling Plan: The Role of Technical Assistance in Promoting Efficiency

The scaling and communication strategy for this research works on three levels: the state of Gujarat where the experiments have been conducted, the national level in India and the global level, where the findings will be relevant to environmental, climate and energy policy. The scale-up work will be conducted by both Principal Investigators and J-PAL's managerial staff and dedicated policy group, formed in order to reach out to policy-makers with experimental results. In South Asia, key staff for this effort include Deputy Director John Floretta, Senior Research Manager Vipin Awatramani and Policy Manager Shailesh Rai, who have all been developing expertise in energy and environment and contacts with policy-makers in the various states where we work.

In Gujarat, the scaling strategy works through the state government, utilities and industrial associations. Our team is working on having the findings of the energy study inform state policies to encourage energy efficiency. Large plants are presently required to hire energy consultants to review plant performance every three years. The Gujarat Energy Development Agency and the office of the Industries Commissioner both work to encourage energy audits for small plants, though these programs work on a very small scale relative to the industrial economy in the state. A trial that found energy-efficiency to be effective may encourage the government to better fund and design these policies to have an impact on state-wide energy use.

A second channel at the state level through which the study might affect energy use is working with electric power utilities. We have agreed to collect some energy use data centrally from the power company in order to monitor plant energy use over time. Utilities presently encourage conservation through non-linear electricity tariffs that reward some aspects of efficiency, like accurately predicting one's electricity load. The results of the study may help utilities set optimal charges to promote efficiency in electricity use.

Finally, the project is undertaken in partnership with industry associations. For every surveyed plant, we will provide feedback to the plant itself and, in an anonymous fashion, to the association, benchmarking plant performance against sectoral peers and suggesting opportunities for improvement, as estimated by the treatment effects. The combined membership of the associations engaged in the program is in the several thousands, and peer-benchmarked information can be powerful in competitive industries, so this feedback may have an immediate effect on plant behavior.

At the national level the scaling strategy focuses on working with the Bureau of Energy Efficiency to institutionalize the lessons of the research. The research team has also opened the channel to energy policy at the national level by partnering with The Energy and Resources Institute (TERI) to conduct the end-line survey of technology adoption and energy use. TERI is the most respected energy research organization in India, with activities spanning from the ground level of technology development to the international policy stage. TERI's Director General, R K Pachauri, is also the chair of the Intergovernmental Panel on Climate Change. We have also engaged with the Bureau of Energy Efficiency in discussion of their national small- and medium-enterprise energy-efficiency programs and expect that this agency will be very responsive to the study findings. As the BEE certifies auditors nationwide and itself promotes industrial energy efficiency with large-scale expenditures of domestic and international aid, we believe it will be critical in promptly bringing findings to scale. In particular, this research can guide BEE's certification process, indicate what industrial plants will save the most energy per policy dollar spent on audits, and identify technologies particularly suitable for direct promotion.

Findings on the true returns to energy-efficient technologies and the best way to promote their adoption will be relevant not only within India but also globally. The U.S. is currently promoting a piecemeal policy of subsidies for renewable-energy and energy-efficiency. This experiment will measure how the characteristics of technologies affect their adoption and the energy-savings they achieve and in this way can inform how governments could effectively go about tilting the energy playing field to promote sustainable energy use. Similarly, at the international scale, one of the largest greenhouse-gas abatement initiatives to date is the Green Climate Fund, a proposed $100 billion transfer from developed to developing countries for use in technology development, abatement and adaptation. This experiment can provide evidence on what kind of technologies work to raise efficiency for industry and the manner of delivery that can get these technologies adopted.

“Leveraging Public-Private Partnerships for the Indian and Global Environment” (Grant Ref. AID-OAA-G-12-00007)

Progress Report submitted to USAID-DIV

Nicholas Ryan
J-PAL South Asia at IFMR
28th September, 2012

1. Introduction

This document is a progress report for J-PAL South Asia’s project titled “Leveraging Public-Private Partnerships for the Indian and Global Environment,” a randomized evaluation of energy-efficiency measures in Indian industrial plants, funded in part by USAID under the grant AID-OAA-G-12-00007. Our previous communication on the same project was a joint progress report and scaling plan submitted April 16th, 2012.

The project is a campaign to reduce greenhouse-gas emissions by increasing the efficiency of energy usage at Small- and Medium-Enterprises (SMEs). Many firms fail to undertake energy-efficiency investments that engineering studies show are positive in net present value. By providing Detailed Energy Audits and follow-on technical assistance, the campaign will close this “energy-efficiency gap" between the low observed efficiency of SMEs and their technical potential. Inducing firms to undertake energy-efficiency investments may be a win-win if it saves firms money while reducing greenhouse gas emissions. By conducting energy audit and energy manager interventions as a randomized-controlled trial, the project will accurately measure the returns to investment in energy-efficiency, relative to a control group of firms not induced to adopt energy-saving measures.

2. Progress Report

This section describes the status of the project to date with respect to the third milestone of:

- 100 cumulative Energy consultancy site visits completed
- 50 Industrial site field surveys completed
- Status update to include:
    - Number of follow-on technical assistance visits provided by auditors (after audit)

The estimated completion date for this milestone was originally June 15th, 2012. Delays in energy audit field work have pushed the completion of the activities for this milestone until September. The project has now met these targets for both energy consultancy and field surveys.

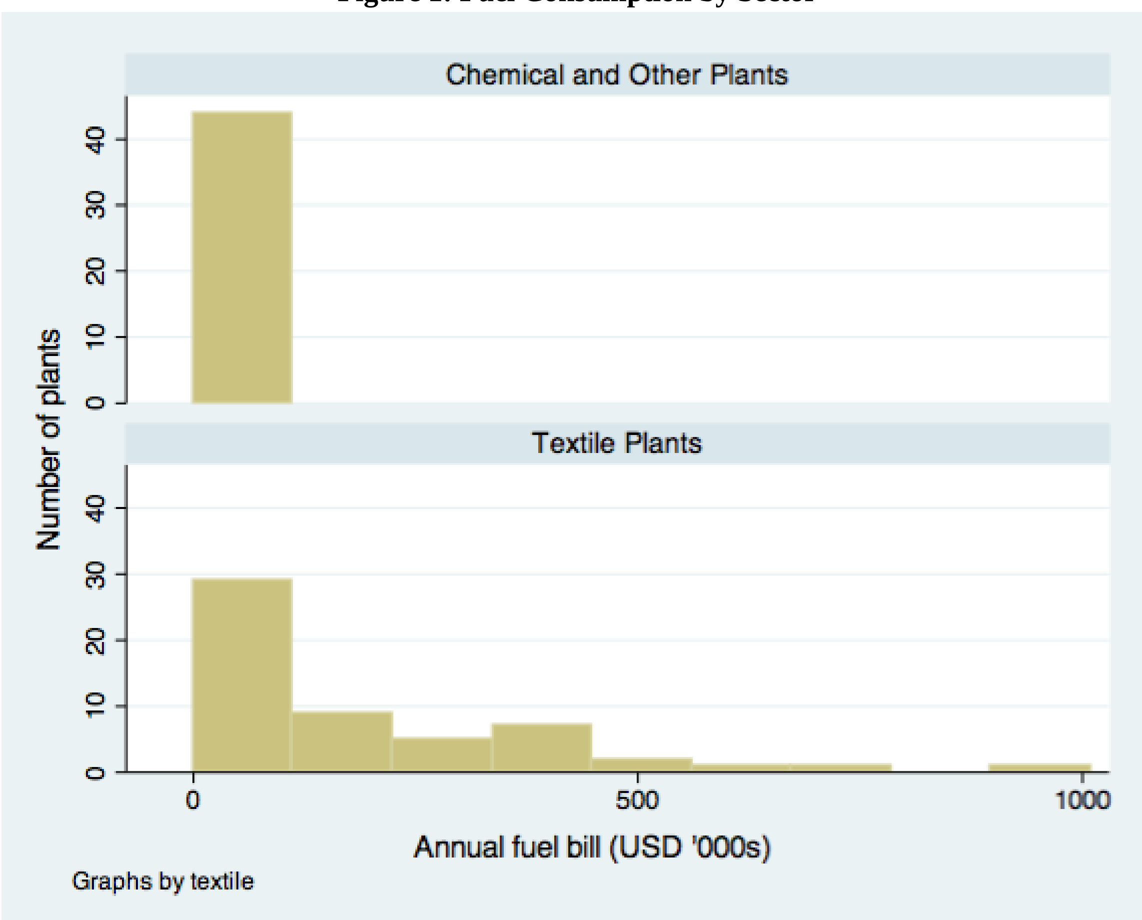
Energy Consultancy Field Work

The energy audits funded by USAID were assigned in the Surat, Ankleshwar and Narol industrial areas by April. The field work for all 100 assignments has now been completed in three associations, with 44 plants audited in Ankleshwar, 6 in Narol and 50 in Surat.

Ankleshwar primarily has Chemical factories whereas Surat and Narol have Textile factories. It is interesting to note the difference in scale and energy use between the plants in these different industrial sectors. Textile factories have a greater capital investment than chemical factories in these areas, and operate continuously, using both electrical energy to drive motors and pumps and thermal energy to heat dyeing liquor, which is used to dye synthetic cloth.

The thermal energy consumption for heating this liquor is surprisingly large. Figure 1 shows the fuel consumption in thousands of US dollars for plants in the sample audited by USAID. The chemical plants, shown in the top panel, do not spend more than $100,000 per year on fuel, whereas textile plants, shown in the bottom panel, spend up to $1m, an enormous expense for a factory still classified as a Small- or Medium-Enterprise.

Figure 1: Fuel Consumption by Sector



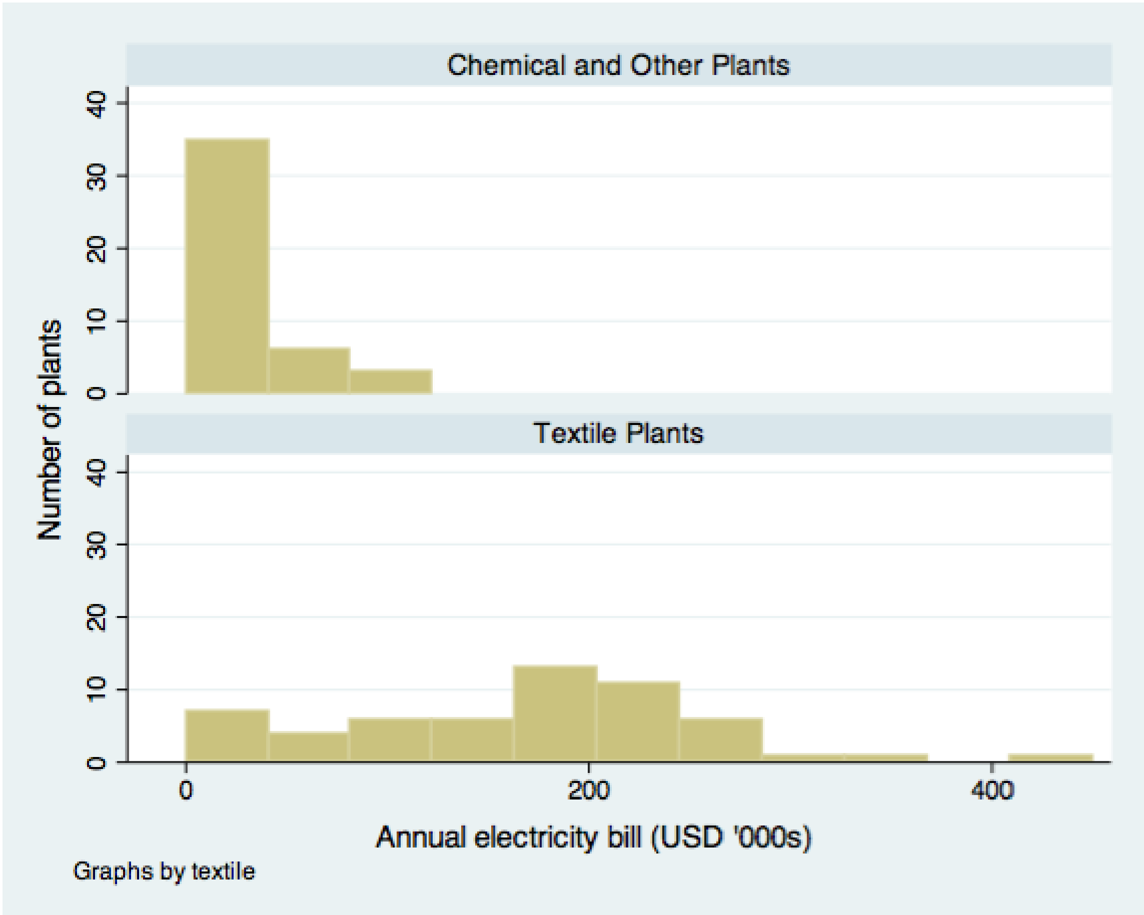
Distribution of Fuel Usage	
Fuel	**Percentage of Plants**
Natural gas	57
Lignite	38
Coal	37
Wood	19
High-sulphur diesel oil	9
Light diesel oil	3
Biomass (other than wood)	3
Coke	1

The table above shows the distribution of fuels used by the same 100 plants. Plants use a range of fuels, mostly solid fuels and heavy petroleum products. The share of fuels used sums up to well above 100%, as many plants switch freely between fuels depending on their prices at the time. A good number of plants, around one in five, use wood. Wood is sometimes classified as a renewable fuel but this designation is controversial as it depends on the manner in which it is harvested.

To complement the graph of fuel consumption, Figure 2 below shows electricity consumption by sector. The largest textile plants consume more electricity than the largest chemical plants in the sample but the gap is not nearly as lopsided as for fuel consumption. Chemical plants often have a large number of motors to drive agitators within reaction vessels.

This is a very light, first characterization of energy use in these plants. We will be working with the data from energy audits and endline surveys in much greater detail in order to characterize the micro-details of energy consumption and the savings actually achieved through this program.

Figure 2: Electricity Consumption by Sector



Follow-on Field Visits

Auditors in the program have completed 11 follow-on field visits to plants in the sample audited by USAID with a further 28 visits pending, for a total of 39 planned. "Visit" is a misnomer here, as each visit is an ongoing implementation assistance relationship that involves the drafting of a plan for the adoption of measures suggested in energy audit reports and two rounds of reporting, over the course of several months, to J-PAL while the consultant works with the plant to pursue these measures.

Because the implementation assistance arm of the project is also randomized within those plants receiving audits, we typically aim for half of the audited plants in a given group to receive implementation assistance also. The rate of 39/100 planned here is somewhat lower than half, but accounts for the fact that some plants are not interested to implement audit recommendations, for example if the initial investments described in the report are too high.

Industrial Site Field Surveys

J-PAL South Asia has completed 55 industrial site field surveys (endline surveys) to date, exceeding the target of 50 for the third milestone. These endline surveys are being conducted with The Energy Resources Institute (TERI), New Delhi as a technical partner. TERI has a deserved reputation as the leading non-governmental organization working in the energy sector in India, and in particular on energy issues in the Small- and Medium-Enterprise sector.

J-PAL has designed and piloted a survey instrument with TERI and used this instrument to measure the energy consumption at the fifty-five plants to date. This number is expanding by the day as our team is presently in Surat working on further surveys in textile factories there. The responsibility for each survey is divided between J-PAL's field monitors, who ask questions of the plant management regarding investments and energy use, and TERI's engineers, who collect field measurements of the performance of various equipment around the plant.

Because of the quality of the survey process and the level of cooperation from both audited and not-audited (i.e., control) units to date, ***we are confident in meeting the final milestone of 100 total industrial field surveys. The completion of the ongoing survey round in Surat will bring us to around 85 surveys and subsequent rounds in Ankleshwar will surpass the target, probably in October or November***. The major obstacle to smooth surveying over this period will be a high number of holidays, which require interruption in work and constant attention to rescheduling units for the survey.

"Leveraging Public-Private Partnerships for the Indian and Global Environment"
(Grant Ref. AID-OAA-G-12-00007)

Final Progress Report submitted to USAID-DIV

J-PAL South Asia at IFMR
23 March, 2012

I. Executive Summary

A. Motivation

This document is the final progress report, scaling plan and policy-influence plan for J-PAL South Asia's project titled "Leveraging Public-Private Partnerships for the Indian and Global Environment," a randomized evaluation of energy-efficiency measures in Indian industrial plants, funded in part by USAID under the grant AID-OAA-G-12-00007. Our previous communications on the same project were a progress report submitted in September, 2012 and a request for extension submitted in December, 2012.

The project is a campaign to reduce greenhouse-gas emissions by increasing the efficiency of energy usage at Small- and Medium-Enterprises (SMEs). Many firms fail to undertake energy-efficiency investments that engineering studies show are positive in net present value. By providing Detailed Energy Audits and follow-on technical assistance, the campaign will close this "energy-efficiency gap" between the low observed efficiency of SMEs and their technical potential. Inducing firms to undertake energy-efficiency investments may be a win-win if it saves firms money while reducing greenhouse gas emissions. By conducting energy audit and energy manager interventions as a randomized-controlled trial, the project will accurately measure the returns to investment in energy-efficiency, relative to a control group of firms not induced to adopt energy-saving measures.

B. Progress Report

The project activities funded by US AID have been completed in full. These activities include 100 cumulative Energy Consultancy site visits and 100 cumulative Industrial Site Field Surveys. Follow-on technical assistance was further provided for 39 units out of the 100 units given Energy Consultancy.

With co-funding, the scale of the project extends beyond the US AID grant. Approximately 180 Energy Consultancy site visits have been completed in total and 125 Industrial Site Field Surveys in total. The total sample of units numbers just over 400; thus the US AID grant has been leveraged into a project of significantly wider scope.

C. Preliminary Findings

We report preliminary findings on the results of Energy Consultancy visits and on estimates of technology adoption and energy-savings due to audits. The results are based on the endline survey data collected thus far with funding from US AID for 100 plants. The project has a total sample size and therefore survey scope of 400 plants and the balance of the surveys are ongoing, with a target completion date of 30 June. Therefore all results presented here are based on a partial sample and are statistically imprecise. They should be taken as preliminary and suggestive and only for the internal use of meeting US AID milestones.

In this preliminary sample, we estimate that on average treatment plants increased electricity use by 4.5% and fuel use (actually fuel bills) by 16%, both statistically not different from zero in the sample of plants so far surveyed. Electricity bills are measured more reliably than fuel consumption and the increase in electricity use has a p-value of 16%. We also find that firms in the treatment invest on average Rs. 11,000 in energy-efficiency upgrades and maintenance. These effects are visible in the significantly greater use of steam traps and, though not statistically significant, higher electricity contract demand in the treatment. Treatment firms appear to operate their equipment more hours during the month.

Could the audit treatment, which was intended to identify investments to save energy, be responsible for an *increase* in energy use? Yes, it could, and this hypothesis warrants further investigation as more survey data arrives and data analysis continues. Improvements in efficiency may, in theory, induce newly more efficient plants to expand production via a positive use-elasticity or "rebound" effect: when my plant is more efficient, I should use it more intensively. Empirical evidence on such an effect is relatively thin but has been seen in some studies of consumer electricity use. It is possible that such an effect is at work here for industrial plants, and if so would be of enormous policy relevance.

D. Scaling and Policy Dissemination

The final section of the document is a Scaling and Policy Dissemination plan. Industrial energy-efficiency is an extremely active area for policy in India and the course of this project has already engaged many of the relevant policy-making bodies. At the national level, the Bureau of Energy Efficiency is an important audience for policy dissemination. The BEE was established in 2002 to promote energy conservation across all sectors in India and, over the last decade, has served as a nodal agency for work on industrial energy-efficiency in India, including by many international agencies.

We identify the most important implementing and policy-making bodies for energy-efficiency at the state, national and global levels, starting from the project context of Gujarat. The scaling and policy dissemination plan studies the activities and goals of each concerned agency to identify channels of policy influence, through which our findings, once finalized, can become part of policy on industrial energy-efficiency and energy- and carbon-intensity more broadly.

II. Progress Report

A. Summary of Progress

The project has been completed in full as awarded by US AID. The table below gives a summary of the project with respect to each component of the final milestone (number four) in the US AID award agreement.

Table 1: Completion of Final Milestone

See Section	Milestone Component	Status
II.B	100 cumulative Energy Consultancy site visits completed	Completed in full, as reported in the September progress report. With co-funding, completed approximately 180 Energy Consultancy site visits.
II.D	100 cumulative Industrial Site Field Surveys completed	Completed in full. 90 site visits had been completed in December and now, with-co-funding, 125 have been completed, with additional Field Surveys ongoing.
	Status Update to Include:	
II.C	Number of follow-on technical assistance visits provided by auditors (after audit) (by test cohort/innovation)	Amongst the 100 industrial units audited under the award, follow-on technical assistance visits were provided for 39 units out of 44 assigned.
II.E	Total energy reduction after intervention of sample small- and medium-enterprises (by test cohort/innovation)	We estimate that on average treatment plants *increased* electricity use 4.5% and fuel use (actually bills) by 16%, both statistically not different from zero in the sample of plants so far surveyed.
II.F	Number of firms undertaking energy-efficiency investments attributable to audit assessment and follow-on technical assistance (by test cohort/innovation)	We find that firms in the treatment invest on average Rs. 11,000 in energy-efficiency upgrades and maintenance. These effects are visible in the significantly greater use of steam traps and, though not statistically significant, higher electricity contract demand in the treatment.
III	Final scaling plan, policy dissemination report	Scaling plan and policy dissemination report attached below.

The rest of this section, from subsections II.B through II.F, addresses the components of the fourth milestone in detail. We describe the project activities and offer supporting data analysis using the data collected in Energy Consultancy field visits and Industrial Field Surveys.

B. Energy Consultancy

Milestone Component: 100 cumulative Energy consultancy site visits completed

The primary treatment in this project consists of providing Energy Consultancy to manufacturing plants to encourage them to invest in energy-efficiency and reduce energy consumption. This consultancy involves a 2-4 day site visit to collect information on energy consumption, which consultants analyze and present to the plant's owner in a Detailed Energy Audit.

The energy audits funded by USAID were assigned in the Surat, Ankleshwar and Narol industrial areas by April, 2012. The field work for all 100 assignments has been completed in three associations, with 44 plants audited in Ankleshwar, 6 in Narol and 50 in Surat. We now describe the characteristics of these plants and their energy usage and then briefly present an overview of the recommendations from Detailed Energy Audits.

The sample was chosen to be represent two important and energy-using manufacturing sectors. The Textile and Chemical sectors are the two biggest in India by employment and have from 5% to more than 25% of their costs due to energy. Table 2 below shows the distribution of industries across sectors in the sample. In the study sample, Ankleshwar primarily has Chemical factories whereas Surat and Narol have Textile factories. Textile plants all dye and print synthetic fabrics. Chemical plants are more diverse, and make products ranging from dyes (used by the Textile plants) to pesticides and pharmaceuticals.

Table 2: Sector of Industrial Plants with Energy Consultancy funded by USAID

Sector	Number of Plants
Chemicals (Other than below)	22
Dyes	9
Dyes Intermediates	3
Pharmaceuticals	7
Textiles	56
Other	3
Total	100

Table 3 gives the characteristics of plants in the sample. The average plant has a contract demand of 255 kVA. Contract demand is how much electric power the unit has a contract with the distribution company to draw and is a good indication of the scale of the unit's energy demand. That average contract demand corresponds to an average annual electricity bill of $108,000. Plants have an even larger expenditure on fuel, $231,000 per year. Though many of these plants are technically classified as Small- and Medium-Enterprises, they employ 120 people on average and have sales of around $2m.

Table 3: Characteristics of Audited Plants

	Mean	**SD**
Contract demand (kVA)	255.4	(171.3)
Annual electricity bill (USD '000s)	108.0	(102.8)
Annual fuel bill (USD '000s)	230.7	(543.4)
Employees	119.5	(129.3)
Capital (USD 000s)	565.5	(584.6)
Sales (USD 000s)	1949.1	(2640.4)
Observations	100	

It is interesting to note the difference in scale and energy use between the plants in these different industrial sectors. Textile factories have a greater capital investment than chemical factories in these areas, and operate continously, using both electrical energy to drive motors and pumps and thermal energy to heat dyeing liquor, which is used to dye synthetic cloth. Figure 1 shows the fuel consumption in thousands of US dollars for plants in the sample audited by US AID. The chemical plants, shown in the top panel, do not spend more than $100,000 per year on fuel, whereas textile plants, shown in the bottom panel, spend up to $1m on fuel alone.

Figure 1: Fuel Consumption by Sector

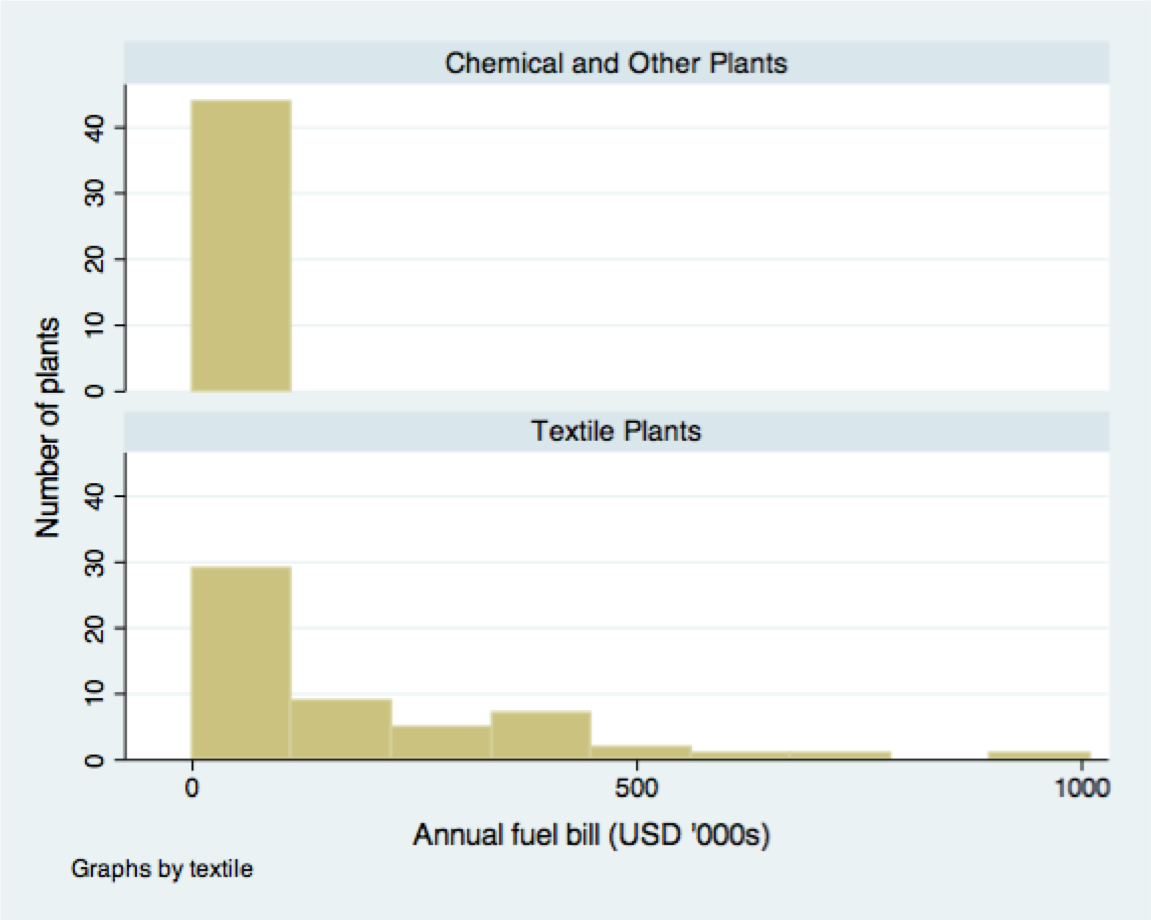


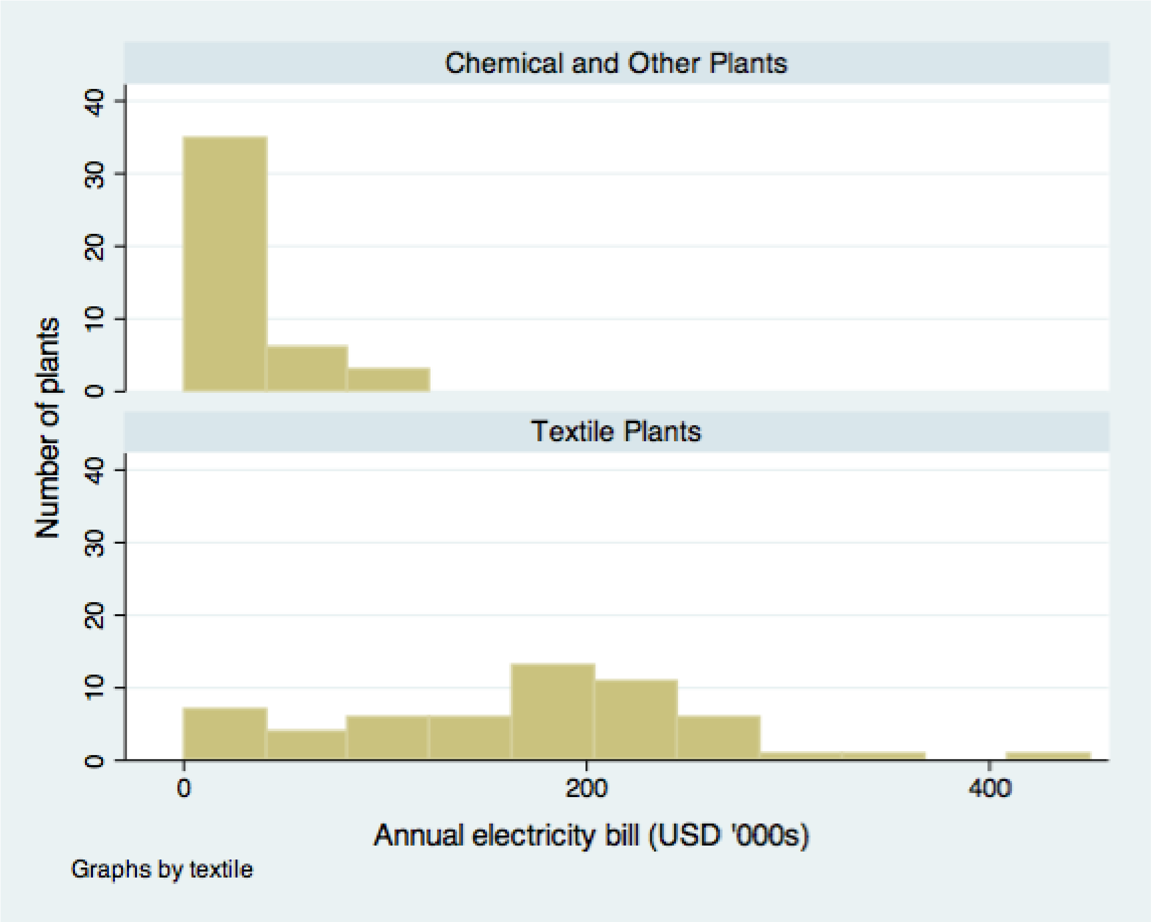
Table 4: Distribution of Fuel Usage

Fuel	Percentage of Plants
Coal	37
Coke	1
Lignite	38
Light diesel oil	3
High-sulfur diesel oil	9
Natural gas	57
Wood	19
Biomass (other than wood)	3

Table 4 above shows the distribution of fuels used by the same 100 plants. Plants use a range of fuels, mostly solid fuels and heavy petroleum products. The share of fuels used sums up to well above 100%, as many plants switch freely between fuels depending on their prices at the time. A good number of plants, around one in five, use wood (this number has increased over the course of the study, as natural gas prices have risen). Wood is sometimes classified as a renewable fuel but this designation is controversial as it depends on the manner in which it is harvested.

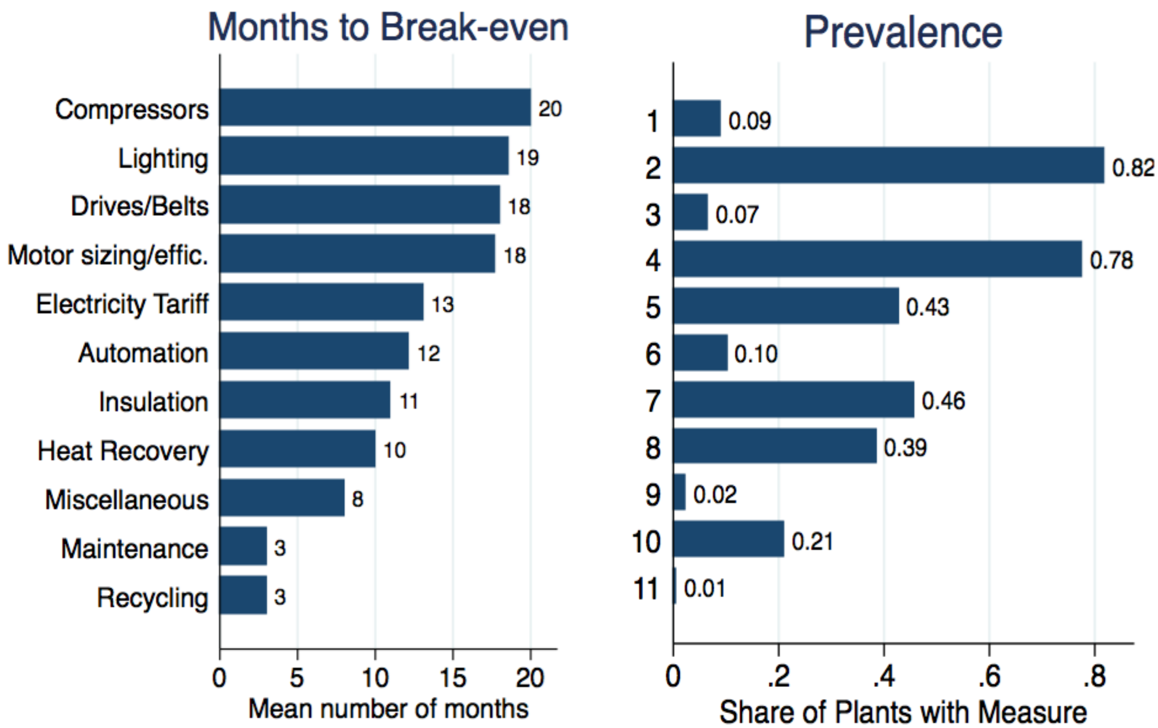
To complement the graph of fuel consumption, Figure 2 below shows electricity consumption by sector. The largest textile plants consume more electricity than the largest chemical plants in the sample but the gap is not nearly as lopsided as for fuel consumption. Chemical plants often have a large number of motors to drive agitators within reaction vessels, which mix chemicals around to promote a reaction and produce a uniform output.

Figure 2: Electricity Consumption by Sector



The goal of Energy Consultancy is to measure the uses of energy in a plant and present recommendations for how the plant could be made more efficient, i.e. use less energy input for the same output. The Detailed Energy Audit report recommends specific investments for the plant to make in order to improve its efficiency. Figure 3 shows the characteristics of recommended measures in two panels. The panel on the left gives the mean number of months to break-even by the type of measure. The months to break even is equal to total investment / projected monthly energy savings and is a simple way of measuring the rate of return: investments with a long time to break even have a lower rate of return. The panel on the right gives, for the same investment types, the share of plants that had a recommendation for such an investment.

Figure 3: Summary of Detailed Energy Audit Recommendations



The Figure makes two important points. First, the number of months to break-even in recommendations is generally very short. The longest for any measure is 20 months, meaning that, according to the projections of consultants, and without any discounting, investments in compressors can be totally recovered in less than two years from a reduction in energy bills. The months to break-even for other investment types are even lower, especially for measures based on maintenance and the like that have little up-front investment at all. Second, the range of measures covered is broad and appears to be related to the simplicity of measures as much as their returns. About 80% of plants have recommendations concerning lighting and motor sizing or efficiency. About 40% of plants have recommendations on insulation or heat recovery. These measures are relatively simple and "stand-alone." Other measures with comparable paybacks, such as automation (e.g. of boiler feeding and temperature control), may be less prevalent because they are more complex to implement.

Figure 4: Aggregate Projected Return on Detailed Energy Audit Recommendations

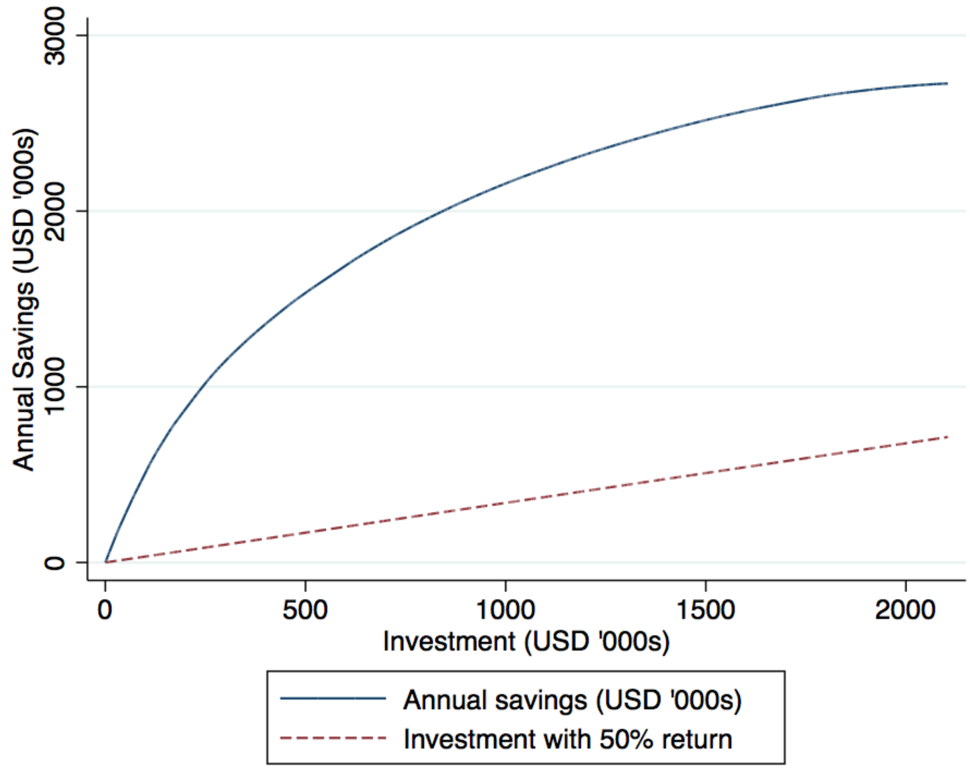


Figure 4 above summarizes the projected returns across all measures recommended and all plants. The horizontal axis is the amount of investment required and the vertical axis the projected annual savings in energy costs. The dashed line gives, for reference, the slope of an investment with a 50% annual return on this scale. Initial investments in energy efficiency, starting from the left, are projected to have very high returns, with the first $500,000 of investment yielding about $1.5m in annual savings. The projected returns then curve downwards fairly quickly and taper off after about $2m in investment.

The two Figures then give a coherent picture of measures recommended in energy audits. Such measures are numerous and have initially high returns but are limited in scope. The relevant questions for the experiment are then: How far along this curve of projected returns are plants actually willing to invest? How much energy do these investments actually save? The next section gives some preliminary answers to these questions.

C. Follow-on Technical Assistance

Number of follow-on technical assistance visits provided by auditors (after audit) (by test cohort/innovation)

Auditors in the program have completed follow-on field visits for 39 plants in the sample audited by USAID out of the total 44 plants assigned to the implementation treatment. Each visit is part of an ongoing implementation assistance relationship that involves the drafting of a plan for the adoption of measures suggested in energy audit reports and two rounds of reporting, over the course of several months, to J-PAL while the consultant works with the plant to pursue these measures.

Table 5: Implementation Treatment Status
For Units in USAID Audit Treatment Group

	Control	Treatment	Not assigned	Total
Treatment Assignment	44	44	12	100
Treatment Completed		39		39

Because the implementation assistance arm of the project is also randomized within those plants receiving audits, we typically aim for half of the audited plants in a given group to receive implementation assistance also. The rate of 39/100 here is somewhat lower than half, but accounts for the fact that some plants are not interested to implement audit recommendations, for example if the initial investments described in the report are too high.

D. Industrial Site Field Surveys

Milestone Component: 100 cumulative Industrial site field surveys completed.

To measure the effect of Energy Consultancy treatments on technology adoption and energy consumption, the project includes detailed Industrial Site Field Surveys (endline surveys) that measure both economic and technical outcomes. The 100 Industrial Site Field Surveys funded by USAID have been completed in the Vatva, Ankleshwar and Surat industrial areas. (Note that, because the Surveys include both treatment and control plants, the 100 units Surveyed overlap with but are not wholly the same as the 100 units treated with Energy Consultancy and described above.) With co-funding, we are continuing the survey through the rest of the sample, with an overall target of 400 plants.

The Surveys are unique in their hybrid scope, covering both technical and economic outcomes. On the technical side, these Surveys are being conducted with The Energy Resources Institute (TERI), New Delhi as a technical partner. TERI has a reputation as the leading non-governmental organization working in the energy sector in India, and in particular on energy issues in the Small- and Medium-Enterprise sector. As part of this survey, TERI engineers measure the energy consumption due to specific pieces of equipment in each plant and calculate the efficiency of various plant systems. J-PAL completes the economic portion of the survey on plant energy bills, inputs and outputs.

IMPORTANT DISCLAIMER ON RESULTS BELOW

The results below in Sections E and F are based on the endline survey data collected thus far with funding from US AID for 100 plants. The project has a total sample size and therefore survey scope of 400 plants and the balance of the surveys are ongoing, with a target completion date of 30 June. The experiment was designed to measure an 8% change in electricity use in a sample of 400 plants.

Therefore, because of the partial sample coverage, the results to date are extremely preliminary and subject to change. Most differences are not statistically significant as the sample is only partially complete and therefore under-sized for the effects of interest. All results below are subject to change and we offer only tentative interpretations of their meaning.

E. Total Energy Reduction

Total energy reduction after intervention of sample small- and medium-enterprises (by test cohort/innovation),

The first table of tentative results from the endline survey shows regressions of total energy use on treatment status. The energy data are from bills and estimates collected during the endline survey at the plant by month level. Electricity data are generally extremely reliable, as these are recorded directly off of the bills provided by the power company for every plant. Fuel use and billing data are somewhat less reliable, as the sources and quality of documentation differ by fuel source (e.g., bills for natural gas are very accurate, whereas records of coal or wood consumption may be inaccurate).

Table 6: Energy Consumption on Treatment

	(1) Monthly Electricity Demand (kWh)	(2) Monthly Electricity Bills (Rs)	(3) Monthly Electricity Energy Charges (Rs)	(4) Total fuel bill (Rs)
Audit treatment assignment (=1)	3146.6	38588.6	36704.7	78092.3
	(3625.6)	(26735.4)	(25908.3)	(137394.9)
Fuel bill, annual				0.0402***
				(0.0104)
Constant	68995.7***	427023.7***	414283.6***	207174.0***
	(2316.3)	(17152.1)	(16368.2)	(71514.6)
Observations	1225	1193	1193	355

Electricity regressions include dummy variables for baseline electricity consumption strata as controls.
Standard errors in parentheses clustered at the plant level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6 shows that the energy-audit treatment is associated with a positive but statistically insignificant *increase* in energy bills, both for electricity and fuel. In the first column, total electricity use increased by about 3,000 kWh per month, or 4.5% of control energy use (for benchmarking purposes, an average American home uses about 1,000 kWh a month, so this could be thought of as an increase of three U.S. homes). This increase is reflected in an increase in total electricity bills (column 2) and in particular in the energy or variable charge component of those bills (column 3). The increase in variable charges in column 3 has a p-value, the probability of finding such a positive result were the true effect actually zero, of 16%. Finally in column 4 the total fuel bill is also estimated to increase by Rs. 78,092, or 16% of the mean fuel bill of about Rs. 500,000 per month. (Note that the mean fuel and electricity bills are both around the same level, Rs. 500,000 or USD 10,000 per month).

Could such an increase be a legitimate effect of the audit treatment, which was intended to identify investments to save energy? Yes, it well could, and this hypothesis warrants further investigation. Energy-efficiency investments, by improving the efficiency of the plant, mean that a given energy input can produce more output. If the plant aims to produce the same output, energy use will fall with improved efficiency. However, improvements in efficiency may, in theory, induce newly more efficient plants to expand production via a positive use-elasticity or "rebound" effect. Empirical evidence on such an effect is relatively thin. One recent and rigorous study of consumer appliance use in Mexico has found that rebound effects caused the distribution of more efficient air conditioners to increase energy use (David, Fuchs and Gertler, "Cash for Coolers", NBER Working Paper No. 18044, 2012). It is possible, and would be of enormous policy relevance, if such an effect were at work here for industrial plants.

F. Energy-Efficiency Investments

Firms undertaking energy-efficiency investments attributable to audit assessment and follow-on technical assistance (by test cohort/innovation)

Any effect of the treatment on energy use should come through that plant's investment in and operation of energy-using equipment. To investigate this channel, Table 7 presents the impact of the treatment on investment in equipment upgrades and equipment operation. We find that the treatment has a positive but modest and statistically insignificant effect on investments in equipment. Treatment plants invest, on average, about Rs. 11,000 more in equipment and maintenance than control plants (because some upgrades may be classified as maintenance, the total is probably the most reliable measure of investment). These differences are estimated very imprecisely in the small sample and the treatment effects are not significantly different from zero. At the plant level, we also look at the reported hours of operation for each piece of equipment each month. Hours of operation increase by an estimated 23 hours (standard error 37 hours) per month, which is positive and statistically insignificant. The point estimate is a roughly 7.5 percent increase over the baseline hours of operation.

Table 7: Investment in Equipment by Treatment Status

	Treatment	Control	Difference
Equipment, cost of upgrade (Rs)	32392.3	28508.1	3884.2
	[83096.3]	[96561.3]	(15962.6)
Equipment, cost of maintenance (Rs)	15532.3	8236.1	7296.2
	[92424.8]	[24050.8]	(12113.1)
Equipment, operating hours per month	331.8	308.8	23.0
	[217.2]	[197.6]	(36.9)

* p lt 0.10, ** p lt 0.05, *** p lt 0.01

From aggregate investments and operation we can zoom further into the plant operations to see whether there is evidence consistent with improved plant efficiency. We have just begun this analysis and present overview tables of two of the most important plant systems, the boiler and related equipment and the electrical distribution system. The boiler is where fuel is consumed, in order to generate heat or steam used in the plant, and the electrical distribution system is where electricity reaches the plant and is distributed to various productive uses. These two systems are important for the efficiency of fuel and electricity consumption, respectively.

Table 8: Boiler Efficiency Features by Treatment Status

	Treatment	Control	Difference
Heat recovery system	0.38	0.37	0.013
	[0.40]	[0.35]	(0.070)
Steam traps	0.48	0.33	0.15**
	[0.38]	[0.29]	(0.063)
Combustion control	0.58	0.71	-0.12
	[0.47]	[0.43]	(0.084)
Insulation	0.90	0.88	0.011
	[0.26]	[0.30]	(0.052)
Feed water pump	0.67	0.70	-0.027
	[0.36]	[0.34]	(0.065)
ID/FD fans	0.89	0.87	0.021
	[0.28]	[0.32]	(0.055)
Observations			

* p lt 0.10, ** p lt 0.05, *** p lt 0.01

Tables 8 and 9 are a first look at the detailed components of these systems. In Table 8, we present the prevalence of various efficiency features by treatment status. Of six features presented, most are insignificant, but there is a large and statistically significant increase, of 15 percentage points or nearly 50%, in the use of steam traps in the treatment plants relative to the control. Steam traps remove water that has condensed as steam cools in its distribution around the plant. Installing and maintaining steam traps properly is an important way to reduce steam loss in distribution and therefore improve the overall efficiency of a plant's steam system. It is economically sensible that we would see movement on this investment but not others observed. Steam traps involved relatively modest investments and had low penetration, whereas other investments in boiler efficiency had either higher investment cost (e.g. heat recovery systems) or very high baseline penetration (e.g. insulation). Note that this table only covers whether a feature is present; we intend to investigate in further analysis the efficiency with which each feature is working.

Table 9 is a similar overview of the presence of various features in the electricity distribution system. Unlike the case of the boiler system, there is no single prominent effect of the treatment in terms of features installed. Treatment and control plants are similarly likely to use automatic voltage controllers , capacitor banks and electronic ballasts for lighting, for example. They also have similar power factors, a measure of how much electrical energy is put to effective use. However, there is a fairly large, but statistically insignificant, increase in contract demand for treatment plants of 33 kVA on a base of 158 kVA, about 20%. The contract demand represents how much the plant contracts with the electric utility to regularly draw in terms of electric load. If treatment plants did increase contract demand, this would be consistent with increases in energy use as observed in bills.

Table 9: Electrical Efficiency Features by Treatment Status

	Treatment	Control	Difference
Contract demand, current	191.1	157.7	33.3
	[183.6]	[150.4]	(30.8)
	[0.25]	[0.35]	(0.056)
Control, auto voltage (whether present=1)	0.083	0.10	-0.020
	[0.28]	[0.31]	(0.054)
Power factor	0.91	0.89	0.024
	[0.16]	[0.16]	(0.030)
Capacitor bank (whether present=1)	0.87	0.91	-0.047
	[0.34]	[0.28]	(0.058)
Capacitor bank, rating (kVAR)	144.1	121.5	22.7
	[123.4]	[118.8]	(24.1)
Capacitor bank, power factor adjust, type (automatic=1)	0.76	0.70	0.063
	[0.43]	[0.46]	(0.090)
Lighting, electronic ballasts (present=1)	0.54	0.51	0.024
	[0.50]	[0.51]	(0.11)

* p lt 0.10, ** p lt 0.05, *** p lt 0.01

In summary, the evidence to date on energy-efficiency investments supports the idea of treatment plants making some modest investments in energy-efficient equipment, relative to control. The best estimate is that these investments total only Rs. 11,000 per plant, and a statistically significant change is the increase in the use of steam traps in the treatment. There is also some economically significant but statistically weak evidence of an increase in contract demand. The pattern of preliminary changes support the hypothesis that the treatment did induce efficiency investments but led to increases in capacity utilization and hence energy use. It is too soon to put this conclusion on solid ground but it will be an important hypothesis to test as we collect additional survey data from sample plants.

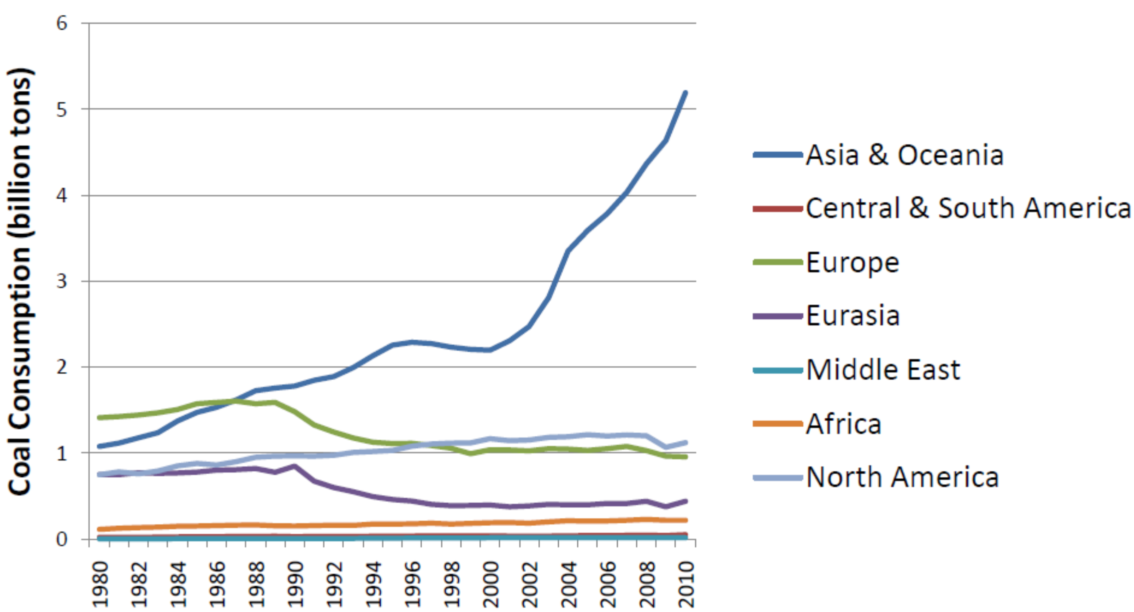
IV. Scaling Plan and Policy Dissemination Report

A. Context for Scaling of Energy-Efficiency Investment

Energy-efficiency is of policy interest at the international, national and local levels. Before describing the scaling and policy dissemination plans it is important to understand the reasons and institutions behind large-scale investment in energy-efficiency as policy.

At the international level, interest in energy-efficiency is driven by its potential to reduce greenhouse gas emissions in the face of rapid economic growth. The baseline growth in emissions from developing countries is plain from Figure 5 below, which shows coal consumption by region of the world over time. Until about 2000, growth in consumption of coal, an important source of carbon dioxide emissions, was modest in Asia and negative in most other regions. Since then, economic growth in India and China has led coal consumption sharply higher, from around 2 billion tons to over 5 billion tons in the course of a decade. Today coal consumption accounts for 43% of global carbon emissions.

Figure 5. Coal Consumption by Region of the World



There are two basic ways to check this growth in emissions—generate energy from cleaner sources, such as solar or wind power, or use less energy per unit of output. The first option will play an important role in mitigation but is expensive and limited in scope; hence developing countries continue to build new fossil-fuel generation plants. As to the second option, energy-efficiency, the head of the U.N. Climate Change Secretariat called energy efficiency “the most promising means to reduce greenhouse gases in the short term.” The planned $100 billion/year Green Climate Fund aims to support a piecemeal approach to mitigation of climate change through technology transfer, including of energy-efficient technologies.

At the national level, the motivation for energy-efficiency is based partly on climate change mitigation but mostly on energy independence or self-sufficiency. India is a net importer of basically all fossil fuels, from oil and natural gas to coal. The prices of many of these fuels have risen and the government struggles to maintain subsidies on several important fuels. At the same time, about 300 million Indians do not have access to electricity and the demand for power, even among those connected to the grid, is often not met. Against these headwinds, the Indian Bureau of Energy Efficiency has National Mission on Enhanced Energy Efficiency across many sectors in order to reduce energy consumption and relieve the country's energy scarcity.

Finally, at the local level, the main concerns around energy-efficiency are a mirror image of national concerns. State utility companies in India generally do not have enough power to supply all their customers continuously, and institute rolling blackouts. Industrial and commercial activity is threatened by an unreliable energy supply. Because industrial and commercial customers often pay higher electricity rates to cross-subsidized agricultural and domestic consumption, these customers have a strong private motivation to invest in energy-efficiency to save money on electricity bills.

B. Scaling Plan

With this context in mind we present a plan to scale the results of this intervention. Because the agencies working to promote energy-efficiency at scale and those that make energy policy are often one and the same, the distinction between scaling and policy is not crisp. We therefore take "scaling" narrowly to mean the application of these findings to energy-efficiency in industrial plants in Gujarat, and "policy dissemination" to be using these findings to influence either the design or implementation of energy-efficiency policy at a national or international level.

The scale-up work will be conducted by both Principal Investigators and J-PAL's managerial staff and dedicated policy group, formed in order to reach out to policy-makers with experimental results. In South Asia, key staff for this effort include Deputy Director John Floretta, Senior Research Manager Vipin Awatramani and Policy Manager Shailesh Rai, who have all been developing expertise in energy and environment and contacts with policy-makers in the various states where we work.

The state of Gujarat, with tens of thousands of industrial plants, is an important setting for industrial energy-efficiency. In the two sectors covered by this study, chemicals and textiles, Gujarat has over 4,000 and 15,000 plants, respectively. Over 2,000 of these plants across both sectors are in the industrial areas of Ankleshwar, Surat, Vatva and Narol covered by this study. The local scaling plan has several different arms to reach out to these plants with information about energy-efficiency.

Direct Feedback to Industry. The project has been undertaken in partnership with industry associations. For every surveyed plant, we will provide feedback to the plant itself and, in an anonymous fashion, to the association, benchmarking plant performance against sectoral peers and suggesting opportunities for improvement, as estimated by the treatment effects. The combined membership of the associations engaged in the program is in the several thousands.

The information in Detailed Energy Audits, as seen in our preliminary results, does not appear to have been powerful in inducing industrial plants to take-up energy-efficiency investments. [TK] The nature of this information, engineering projections of expected energy savings, may not be credible or otherwise a sound basis for action for small enterprises. Information may be more helpful if set within a frame of reference for benchmarking one's own energy-efficiency against the performance of peer plants.

Therefore, to test this hypothesis and use the data from the endline survey on a broad scale, we are designing an informational feedback intervention. This intervention will provide information on where each given plant falls in the distribution of plant efficiency and why—e.g. greater or lower motor efficiency, insulation, boiler efficiency, etc. The main indicators of interest will be output in units of kilograms (chemical sector) and meters (of cloth, in textile sector) per unit of electricity and fuel input. These variables will be presented relative to the same measures for other, peer plants in the same sector, in order that each plant can judge its relative performance with respect to energy-efficiency.

Gujarat Energy Development Agency. Gujarat Energy Development Agency (GEDA) is a part of the Government of Gujarat and is responsible for renewable energy and energy-efficiency programs in the state. GEDA has provided a partial subsidy of INR 20,000 (about USD 400) to plants for energy audits conducted as part of this study. This subsidy reduced the cost to the researchers, and therefore funders, of conducting the study and gives GEDA a stake in the study's results. We have given GEDA an interim report on the findings of Detailed Energy Audits and will update this into a final report after the endline survey is complete. We intend that these reports and our discussion would suggest how GEDA could design its industrial energy-efficiency programs for Gujarat. Large plants are presently required to hire energy consultants to review plant performance every three years. GEDA and the office of the Industries Commissioner both work to encourage energy audits for small plants.

A second channel for scaling is the consultants that GEDA certifies as energy auditors for the state. We worked with eight of these consultants in the study and there are between 30 and 40 certified in all. We have preliminarily discussed with GEDA the idea of holding a conference to discuss lessons and findings from this study with all the energy consultants together, and will plan this conference for sometime in Q2 2013 as the survey concludes.

Gujarat Pollution Control Board. In other research, we have collaborated with the Gujarat Pollution Control Board (GPCB) to study environmental regulation. The GPCB is concerned with plant efficiency from the point of view of minimizing input consumption and output pollution, in particular water and fuel consumption. This goal overlaps with energy-efficiency to some extent as energy-efficient plants will generally use less fuel, water and other inputs, generating less air and water pollution. We will present the results of this study at GPCB, which has an ongoing process-efficiency program for the textiles sector.

Utilities. A second channel at the state level through which the study might affect energy use is working with electric power utilities. We have agreed to collect some energy use data centrally from the power company in order to monitor plant energy use over time. Utilities presently encourage conservation through non-linear electricity tariffs that reward some aspects of efficiency, like accurately predicting one's electricity load. The results of the study may help utilities set optimal charges to promote efficiency in electricity use.

C. Policy Dissemination

Energy-efficiency has lately become a huge focal area for national energy policy in India, which gives this research a natural audience in the organizations that are working on industrial energy-efficiency programs of their own. The Government of India in 2001 enacted an Energy Conservation Act to "provide for the efficient use of energy and its conservation." This Act established a national Bureau of Energy-Efficiency, which subsequently launched a National Mission for Enhanced Energy Efficiency to promote energy conservation across all sectors, including not only industry but also domestic and commercial consumption.

Table 10 on the following page summarizes the biggest efforts for industrial energy-efficiency in small- and medium-enterprises. International donors, including US AID, the World Bank, JICA and KfW have joined the Government's efforts in this sector through several projects at a national scale. These projects have various components but two are most prominently featured. First, detailed or walk-through energy audits, as used in the primary treatment in this study. Second, subsidized financing for energy-efficiency investment. The close link between this study design and recent policy in this area mean that the findings of the study will merit attention at the organizations mentioned, in particular the BEE, TERI, JICA and the World Bank. After the table we describe our plan to disseminate findings to these groups.

Table 10: Major Energy-Efficiency Projects in India

Project	Dates	Agencies	Activity	Scope
World Bank – Global Environment Facility	2012 – 2013	Bureau of Energy Efficiency (BEE), Small Industries Development Bank of India (SIDBI)	Detailed energy audits, capacity building	Ankleshwar, Faridabad, Kolhapur, Pune, Tirunelveli
BEE Small- and Medium-Enterprise (SME) Program	2010 – 2011	BEE	Detailed energy audits, technology identification, capacity building	Over 4,000 units in 35 clusters across India
SIDBI Financing Scheme for Micro, Small and Medium Enterprises	2008 - 2010 (Phase I), 2011	SIDBI, Japanese International Cooperation Agency (JICA)	Financing for SME energy-efficiency through $330m subsidized loan	MSME units from all India, minimum investment grade rating from SIDBI and 10% energy saving potential (Phase II)
Financing Energy Efficiency Projects in the MSME Sector	2012 -	KfW Group, SIDBI	Financing for SME energy-efficiency through $70m subsidized loan	MSME units from all India, minimum investment grade rating from SIDBI
Energy Conservation and Commercialization (ECO) Project, Phase III	2006-2009	US AID, BEE	Feasibility studies, technology development, select investment-grade energy audits	Four SME clusters including Ludhiana, Ahmedabad, Mandi Gobindgarh

At the national level the scaling strategy focuses on working with the Bureau of Energy Efficiency to institutionalize the lessons of the research. The BEE, as is evident from the table, is the nodal agency for most national-scale work on energy-efficiency in India. We solicited the advice of the BEE at the early stages of this project and selected the Chemicals and Textiles sectors for study after consulting with prior BEE data and reports. We will present the findings of the study to the Director and concerned Energy Economists at the BEE.

The Energy and Resources Institute (TERI), our survey partner, is a non-governmental agency but still important for energy policy in India. TERI runs a website for small- and medium-enterprise energy efficiency called Sameeeksha (http://sameeeksha.org/) to share knowledge about energy-efficiency with industry. This platform is a joint venture of TERI, the BEE, the Climate Change and Development Division of the Embassy of Switzerland and the Ministry of Micro, Small and Medium Enterprises. We published a progress report on this study in a issue of the Sameeeksha newsletter in 2012 and will publish an update and present the findings to the Sameeeksha Core Committee once they are final.

Findings on the true returns to energy-efficient technologies and the best way to promote their adoption will be relevant not only within India but also globally. The U.S. is currently promoting a piecemeal policy of subsidies for renewable-energy and energy-efficiency. This experiment will measure how the characteristics of technologies affect their adoption and the energy-savings they achieve and in this way can inform how governments could effectively go about tilting the energy playing field to promote sustainable energy use. At the international scale, one of the largest greenhouse-gas abatement initiatives to date is the Green Climate Fund, a proposed $100 billion transfer from developed to developing countries for use in technology development, abatement and adaptation. This experiment can provide evidence on what kind of technologies work to raise efficiency for industry and the manner of delivery that can get these technologies adopted.

he acting director of the Green Climate Fund is Dr. Ajay Mathur, former Director General of the Indian BEE. We interacted with Dr. Mathur briefly when he was at the BEE and will aim to bring the findings to his attention in his new role by presenting the findings at the Green Climate Fund. The research team has also opened the channel to energy policy at the global level by partnering with The Energy and Resources Institute (TERI) to conduct the end-line survey of technology adoption and energy use. TERI is the most respected energy research organization in India, with activities spanning from the ground level of technology development to the international policy stage. TERI's Director General, R K Pachauri, is also the chair of the Intergovernmental Panel on Climate Change. We will present and discuss the results with partners at TERI to bring them to the attention of policy-makers working on climate change mitigation.

“Leveraging Public-Private Partnerships for the Indian and Global Environment”

Final Progress Report submitted to USAID-DIV

Award AID-OAA-G-12-00007
Milestone 4

J-PAL South Asia at IFMR
9th May, 2013
[Revised version of the 23rd March, 2013 report]

1. Executive Summary

A. Motivation

This document is the final progress report, scaling plan and policy-influence plan for J-PAL South Asia's project titled "Leveraging Public-Private Partnerships for the Indian and Global Environment," a randomized evaluation of energy-efficiency measures in Indian industrial plants, funded in part by USAID under the grant AID-OAA-G-12-00007. Our previous communications on the same project were a progress report submitted in September, 2012 and a request for extension submitted in December, 2012.

The project is a campaign to reduce greenhouse-gas emissions by increasing the efficiency of energy usage at Small- and Medium-Enterprises (SMEs). Many firms fail to undertake energy-efficiency investments that engineering studies show are positive in net present value. By providing Detailed Energy Audits and follow-on technical assistance, the campaign will close this "energy-efficiency gap" between the low observed efficiency of SMEs and their technical potential. Inducing firms to undertake energy-efficiency investments may be a win-win if it saves firms money while reducing greenhouse gas emissions. By conducting energy audit and energy manager interventions as a randomized-controlled trial, the project will accurately measure the returns to investment in energy-efficiency, relative to a control group of firms not induced to adopt energy-saving measures.

B. Progress Report

The project activities funded by US AID have been completed in full. These activities include 100 cumulative Energy Consultancy site visits and 100 cumulative Industrial Site Field Surveys. Follow-on technical assistance was further provided for 39 units out of the 100 units given Energy Consultancy.

With co-funding, the scale of the project extends beyond the US AID grant. Approximately 180 Energy Consultancy site visits have been completed in total and 125 Industrial Site Field Surveys in total. The total sample of units numbers just over 400; thus the US AID grant has been leveraged into a project of significantly wider scope.

C. Preliminary Findings

We report preliminary findings on the results of Energy Consultancy visits and on estimates of technology adoption and energy-savings due to audits. The results are based on the endline survey data collected thus far with funding from US AID for 100 plants. The project has a total sample size and therefore survey scope of 400 plants and the balance of the surveys are ongoing, with a target completion date of 30 June. Therefore all results presented here are based on a partial sample and are statistically imprecise. They should be taken as preliminary and suggestive and only for the internal use of meeting US AID milestones.

In this preliminary sample, we estimate that on average treatment plants increased electricity use by 4.5% and fuel use (actually fuel bills) by 16%, both statistically not different from zero in the sample of plants so far surveyed. Electricity bills are measured more reliably than fuel consumption and the increase in electricity use has a p-value of 16%. We also find that firms in the treatment invest on average Rs. 11,000 in energy-efficiency upgrades and maintenance. These effects are visible in the significantly greater use of steam traps and, though not statistically significant, higher electricity contract demand in the treatment. Treatment firms appear to operate their equipment more hours during the month.

Could the audit treatment, which was intended to identify investments to save energy, be responsible for an *increase* in energy use? Yes, it could, and this hypothesis warrants further investigation as more survey data arrives and data analysis continues. Improvements in efficiency may, in theory, induce newly more efficient plants to expand production via a positive use-elasticity or "rebound" effect: when my plant is more efficient, I should use it more intensively. Empirical evidence on such an effect is relatively thin but has been seen in some studies of consumer electricity use. It is possible that such an effect is at work here for industrial plants, and if so would be of enormous policy relevance.

D. Scaling and Policy Dissemination

The final section of the document is a Scaling and Policy Dissemination plan. Industrial energy-efficiency is an extremely active area for policy in India and the course of this project has already engaged many of the relevant policy-making bodies. At the national level, the Bureau of Energy Efficiency is an important audience for policy dissemination. The BEE was established in 2002 to promote energy conservation across all sectors in India and, over the last decade, has served as a nodal agency for work on industrial energy-efficiency in India, including by many international agencies.

We identify the most important implementing and policy-making bodies for energy-efficiency at the state, national and global levels, starting from the project context of Gujarat. The scaling and policy dissemination plan studies the activities and goals of each concerned agency to identify channels of policy influence, through which our findings, once finalized, can become part of policy on industrial energy-efficiency and energy- and carbon-intensity more broadly.

2. Motivation and Research Design

A. Key Study Questions

Globally, India and China will contribute most to future growth in emissions of greenhouse gases. For example, consumption of coal, a carbon-intensive fuel, is forecast to increase 3% per year from 2004-2030 India and China, versus only 0.6% per year growth in the OECD countries (Stern, 2006). Recognizing the crucial role that low-carbon growth must play in checking future emissions, global climate policy-makers have pushed funding for carbon emissions abatement and mitigation initiatives. The goal of transferring $30 billion from developed to developing economies, set in Copenhagen, was raised to $100 billion less than a year later in Cancun.[1]

This transfer, a combination of public and private investment, can only succeed if it significantly and reliably checks emissions growth. Policies to increase energy-efficiency, ranging from technology mandates and building codes to efficiency credits and energy audits, are some of the most favored abatement options in the near term. For example, McKinsey & Co. has argued that industrial energy efficiency offers some of the lowest carbon abatement costs of any available technology—in fact that it yields positive returns (Naucler & Enkvist, 2009). Economists have heard, and often rebuked, such claims before (Joskow & Marron, 1992). A long literature in economics demonstrates that neither consumers nor firms adopt all technologies that appear profitable in engineering analyses of costs and benefits (Jaffe & Stavins, 1994). The reasons cited for this failure to adopt vary. Market failures may prevent firms from reliably learning about efficient technologies, or a lack of capital, skilled labor and other inputs may inhibit adoption. Most basically, real-world returns to energy-efficiency investments may not match their predicted returns.

They key study questions are therefore:

1. What are the returns to investment in energy-efficiency? Do policy interventions such as energy audits reduce energy use and carbon emissions?

2. Do firms make energy-efficiency investments / adopt energy-efficient technology? What is the relationship between projected and actual energy savings?

3. Why do or do not firms adopt such technology? What are the characteristics of technologies and firms associated with higher or lower adoption and efficiency?

4. Do externalities due to energy use, and the response of firms to energy audits, warrant subsidizing energy audits to improve efficiency?

[1] Wall Street Journal (December 11, 2010), available at http://online.wsj.com/article/SB10001424052748703518604576012922254366218.html

This study will robustly measure the motives for adoption, or non-adoption, of energy-saving technologies with a randomized-controlled trial of industrial energy audits in an important setting. Energy-audits will be conducted for a random subset of interested energy-intensive firms, and their technology choices and energy use tracked against a comparable group of control firms. This will be the first measure of energy audit savings against an experimental counter-factual, which is crucial for separating the effect of audits from rapid changes in the economic environment. The experiment has been designed specifically to draw out the relation between projections of energy savings and energy savings achieved in the real world. A subset of audited firms will receive technical assistance to implement audit recommendations. The provision of information, via audits, and skilled labor from this assistance will identify the true constraints on the adoption of efficient technologies.

B. Study Design: Interventions

The research design is a randomized-controlled trial with two primary intervention arms. These two treatments, energy audits and energy managers, are designed to test the leading hypotheses for why firms do not adopt energy-efficient technologies.

1. *Energy audit intervention.* Out of a total sample of approximately 400 interested factories, half will be randomly chosen to receive energy audits, thorough 5- to 7-day examinations of plant utility and process systems. Audits suggest investments to improve the efficiency of energy use and prioritize such investments by their expected economic return.

The motivation for energy audits as an intervention is the pervasive hypothesis that informational market failures may prevent the adoption of efficient technology. These failures could take two forms. First, asymmetric information between firms and service providers may deter adoption of efficient technologies. If firms are not able to independently evaluate the returns on energy-efficiency investments, energy consultants may oversell their services and drive wary firms to shade their expectation of returns or drop out of the market (DeCanio and Watkins, 1998; Howarth et al., 2000). Second, information about efficiency may be undersupplied in the market because it is a public good. A plant discovering, testing or disseminating a technology in its industry can benefit competitors by providing an example. Because plants do not take this common benefit into account, there will be too little information about efficiency supplied by the market (Anderson & Newell, 2004).

The energy audit intervention overcomes these obstacles by providing information about energy-efficiency, specific to each plant and free of cost. To address asymmetric information specifically, a subset of plants will be selected to have the conclusions of their audits independently verified. To address the possibility that information is a public good, information about efficiency will be publicly provided to treatment plants, so it will no longer matter whether private firms have poor incentives to provide information. The audit and ancillary verification treatments thus independently test the two leading informational hypotheses for non-adoption.

2. *Energy manager intervention.* Out of the sample of 250 audited plants, half (125) will be randomly chosen to receive energy managers, skilled engineers who will stay on in the plant part-time for approximately three months to implement audit recommendations. Energy managers will liaise with service providers, oversee equipment installation and train plant staff on new technology.

The motivation for energy managers as an intervention is to test the relation between skilled labor and technology adoption. A leading alternative to informational hypotheses is that efficient technology is complementary to other productive factors, especially skilled labor. Small plants relying on unskilled labor may therefore rationally choose to be less efficient—there is no use adopting sophisticated process controls that plant staff cannot operate. In this view, engineering estimates of technology savings miss the hidden costs of complementary productive inputs.

The energy manager intervention overcomes this obstacle by providing skilled labor directly. If plants are skill-constrained, then those provided energy managers should adopt a broader set of technologies and save more energy than those provided audits alone. An additional alternative hypothesis is that plants may be constrained not by skill but by credit. To address this concern, plants given energy managers will also be informed about SIDBI's energy-efficiency financing program, which offers subsidized credit specifically to fund adoption of more efficient technologies, and contacted by loan officers. This offer will be given to energy manager plants only, rather than being randomized within all audited plants, as isolating credit constraints is not the main focus of the study. It is preferable to create one all-out treatment group, combining audits, managers and credit, to test the limits of policy.

C. Study Design: Outcome Measures and Sample Size Calculation

The primary outcomes for the study are energy use and technology adoption. Energy use is measured by electricity and fuel consumption and carbon emissions. An energy consultant will visit each firm in the sample, in both treatment and control groups, approximately 6 months after audit completion. The consultant will collect energy use data, record recent investments in energy and other plant equipment, and survey the plant manager on staffing and other subjects. Because the treatment and control group are randomly selected from a common population, they will be statistically comparable when the project starts and any differences between the treatment groups will be causally attributable to the treatments themselves.

The main difficulty in measuring returns to energy-efficiency is that the plants that adopt such technology will not be representative of all other plants. Adopters will generally have adopted because they expected higher returns than non-adopters. The design addresses this problem by stratifying the randomization for the energy manager (joint with credit information) intervention on the projected returns to energy-saving within the energy-audit group. Different firms have different potential savings. All 200 audited firms will be ranked by the amount of energy they could save with a fixed investment (relative to plant size), and the randomization of energy-managers will then be conducted within groups of plants of similar rank. The energy managers will then work to implement recommendations, so that the study may observe returns even for relatively low-return plants that normally would not consider adoption. The design will thus map out the relationship between projected and achieved energy savings. This relationship will test whether returns may appear high on average due only to a small, non-representative subset of plants with very high returns.

The sample size of 400 industrial plants was chosen to detect an 8% drop in electricity consumption with 80% statistical power, using data from a sample of energy audits carried out by the Bureau of Energy Efficiency (BEE) for chemical factories near Ahmedabad. Fuel consumption will also be measured but electricity consumption is the primary outcome because it is less variable and better-measured (using electricity bills). This calculation assumed that the correlation between baseline and endline energy consumption is 0.65. To the extent that this assumed correlation is conservative, and energy use is highly persistent within a plant over the study period, the evaluation will be able to detect smaller decreases in energy use. Against this, to the extent that plants do not participate in the survey, the statistical power will be lessened.

3. Progress Report

A. Summary of Progress

The project has been completed in full as awarded by US AID. The table below gives a summary of the project with respect to each component of the final milestone (number four) in the US AID award agreement.

Table 1: Completion of Final Milestone

See Section	Milestone Component	Status
II.B	100 cumulative Energy Consultancy site visits completed	Completed in full, as reported in the September progress report. With co-funding, completed approximately 180 Energy Consultancy site visits.
II.D	100 cumulative Industrial Site Field Surveys completed	Completed in full. 90 site visits had been completed in December and now, with-co-funding, 125 have been completed, with additional Field Surveys ongoing.
	Status Update to Include:	
II.C	Number of follow-on technical assistance visits provided by auditors (after audit) (by test cohort/innovation)	Amongst the 100 industrial units audited under the award, follow-on technical assistance visits were provided for 39 units out of 44 assigned.
II.E	Total energy reduction after intervention of sample small- and medium-enterprises (by test cohort/innovation)	We estimate that on average treatment plants *increased* electricity use 4.5% and fuel use (actually bills) by 16%, both statistically not different from zero in the sample of plants so far surveyed.
II.F	Number of firms undertaking energy-efficiency investments attributable to audit assessment and follow-on technical assistance (by test cohort/innovation)	We find that firms in the treatment invest on average Rs. 11,000 in energy-efficiency upgrades and maintenance. These effects are visible in the significantly greater use of steam traps and, though not statistically significant, higher electricity contract demand in the treatment.
III	Final scaling plan, policy dissemination report	Scaling plan and policy dissemination report attached below.

The rest of this section, from subsections II.B through II.F, addresses the components of the fourth milestone in detail. We describe the project activities and offer supporting data analysis using the data collected in Energy Consultancy field visits and Industrial Field Surveys.

B. Energy Consultancy

Milestone Component: 100 cumulative Energy consultancy site visits completed

The primary treatment in this project consists of providing Energy Consultancy to manufacturing plants to encourage them to invest in energy-efficiency and reduce energy consumption. This consultancy involves a 2-4 day site visit to collect information on energy consumption, which consultants analyze and present to the plant's owner in a Detailed Energy Audit.

The energy audits funded by USAID were assigned in the Surat, Ankleshwar and Narol industrial areas by April, 2012. The field work for all 100 assignments has been completed in three associations, with 44 plants audited in Ankleshwar, 6 in Narol and 50 in Surat. We now describe the characteristics of these plants and their energy usage and then briefly present an overview of the recommendations from Detailed Energy Audits.

The sample was chosen to be represent two important and energy-using manufacturing sectors. The Textile and Chemical sectors are the two biggest in India by employment and have from 5% to more than 25% of their costs due to energy. Table 2 below shows the distribution of industries across sectors in the sample. In the study sample, Ankleshwar primarily has Chemical factories whereas Surat and Narol have Textile factories. Textile plants all dye and print synthetic fabrics. Chemical plants are more diverse, and make products ranging from dyes (used by the Textile plants) to pesticides and pharmaceuticals.

Table 2: Sector of Industrial Plants with Energy Consultancy funded by USAID

Sector	Number of Plants
Chemicals (Other than below)	22
Dyes	9
Dyes Intermediates	3
Pharmaceuticals	7
Textiles	56
Other	3
Total	100

Table 3 gives the characteristics of plants in the sample. The average plant has a contract demand of 255 kVA. Contract demand is how much electric power the unit has a contract with the distribution company to draw and is a good indication of the scale of the unit's energy demand. That average contract demand corresponds to an average annual electricity bill of $108,000. Plants have an even larger expenditure on fuel, $231,000 per year. Though many of these plants are technically classified as Small- and Medium-Enterprises, they employ 120 people on average and have sales of around $2m.

Table 3: Characteristics of Audited Plants

	Mean	**SD**
Contract demand (kVA)	255.4	(171.3)
Annual electricity bill (USD '000s)	108.0	(102.8)
Annual fuel bill (USD '000s)	230.7	(543.4)
Employees	119.5	(129.3)
Capital (USD 000s)	565.5	(584.6)
Sales (USD 000s)	1949.1	(2640.4)
Observations	100	

It is interesting to note the difference in scale and energy use between the plants in these different industrial sectors. Textile factories have a greater capital investment than chemical factories in these areas, and operate continously, using both electrical energy to drive motors and pumps and thermal energy to heat dyeing liquor, which is used to dye synthetic cloth. Figure 1 shows the fuel consumption in thousands of US dollars for plants in the sample audited by US AID. The chemical plants, shown in the top panel, do not spend more than $100,000 per year on fuel, whereas textile plants, shown in the bottom panel, spend up to $1m on fuel alone.

Figure 1: Fuel Consumption by Sector

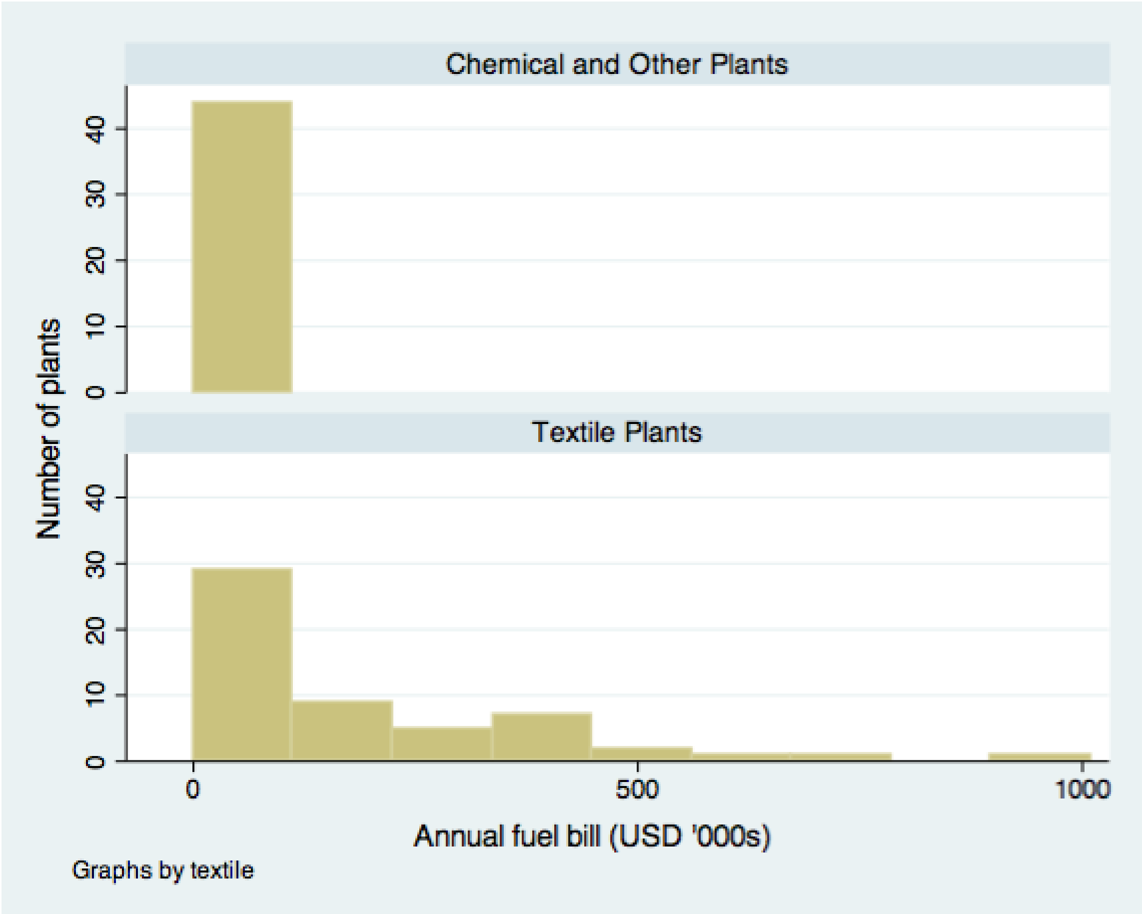


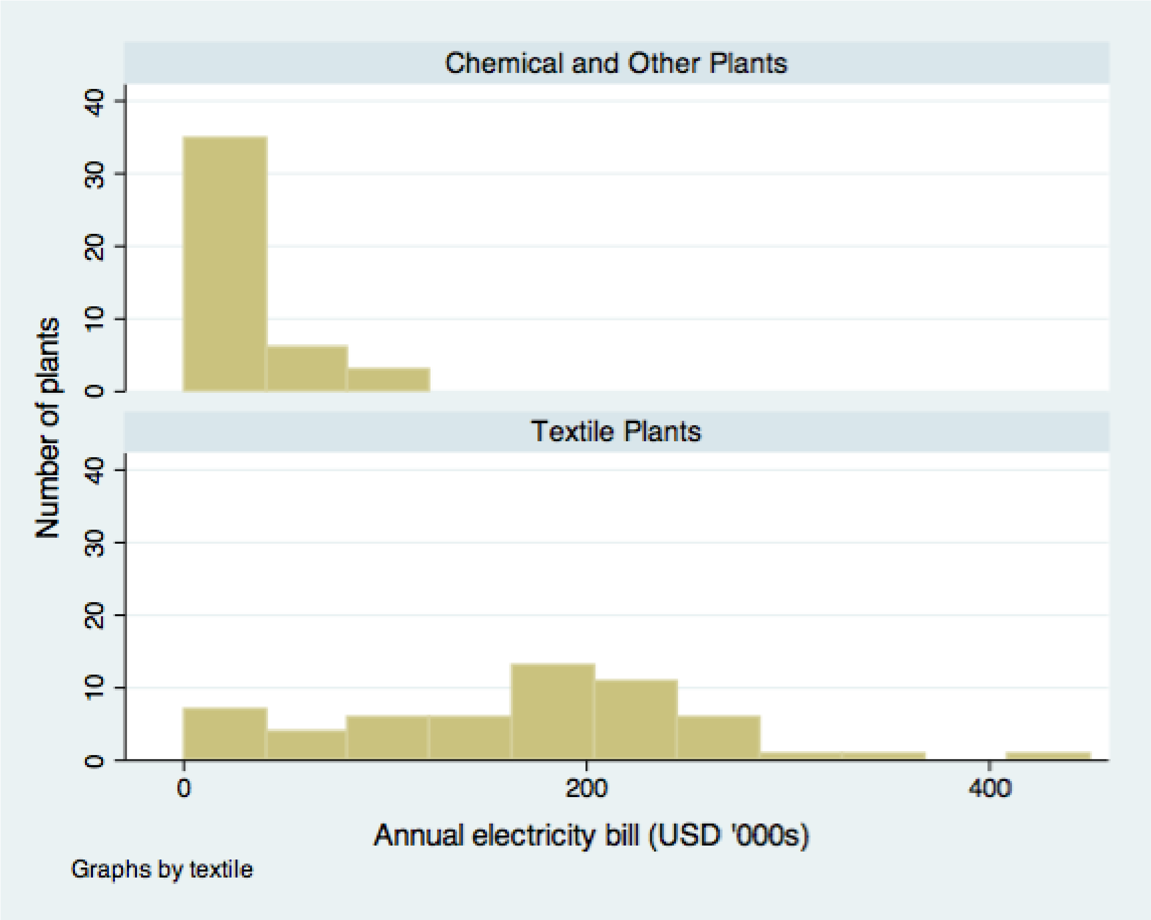
Table 4: Distribution of Fuel Usage

Fuel	Percentage of Plants
Coal	37
Coke	1
Lignite	38
Light diesel oil	3
High-sulfur diesel oil	9
Natural gas	57
Wood	19
Biomass (other than wood)	3

Table 4 above shows the distribution of fuels used by the same 100 plants. Plants use a range of fuels, mostly solid fuels and heavy petroleum products. The share of fuels used sums up to well above 100%, as many plants switch freely between fuels depending on their prices at the time. A good number of plants, around one in five, use wood (this number has increased over the course of the study, as natural gas prices have risen). Wood is sometimes classified as a renewable fuel but this designation is controversial as it depends on the manner in which it is harvested.

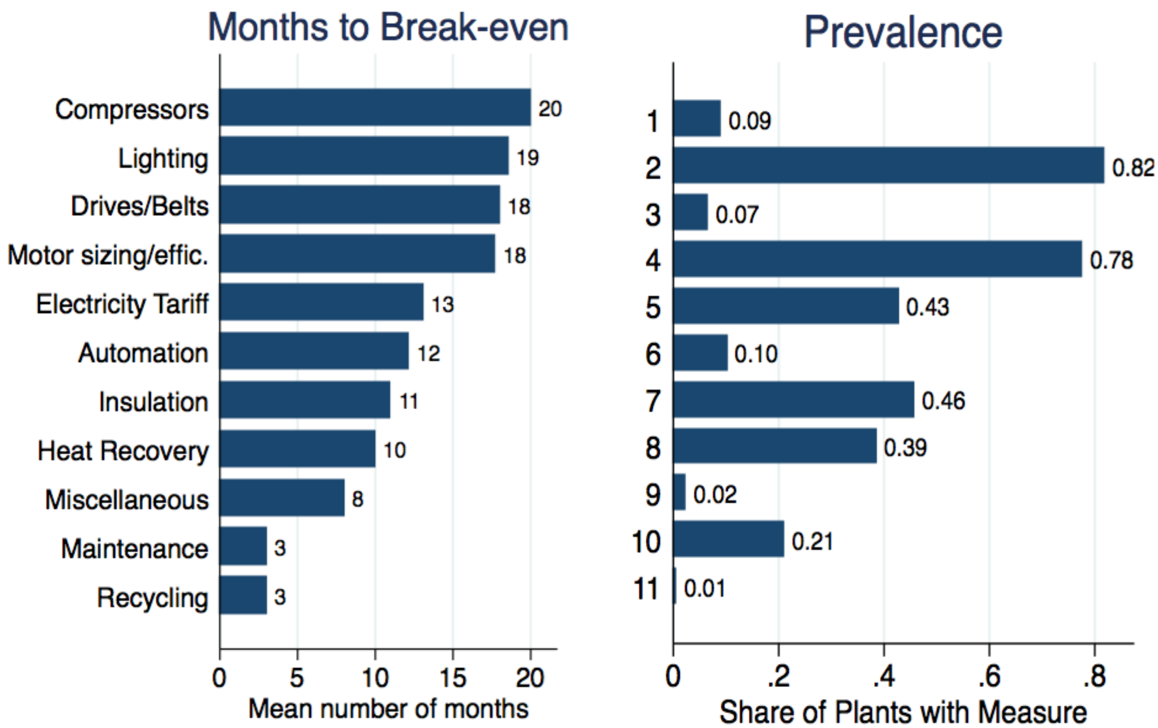
To complement the graph of fuel consumption, Figure 2 below shows electricity consumption by sector. The largest textile plants consume more electricity than the largest chemical plants in the sample but the gap is not nearly as lopsided as for fuel consumption. Chemical plants often have a large number of motors to drive agitators within reaction vessels, which mix chemicals around to promote a reaction and produce a uniform output.

Figure 2: Electricity Consumption by Sector



The goal of Energy Consultancy is to measure the uses of energy in a plant and present recommendations for how the plant could be made more efficient, i.e. use less energy input for the same output. The Detailed Energy Audit report recommends specific investments for the plant to make in order to improve its efficiency. Figure 3 shows the characteristics of recommended measures in two panels. The panel on the left gives the mean number of months to break-even by the type of measure. The months to break even is equal to total investment / projected monthly energy savings and is a simple way of measuring the rate of return: investments with a long time to break even have a lower rate of return. The panel on the right gives, for the same investment types, the share of plants that had a recommendation for such an investment.

Figure 3: Summary of Detailed Energy Audit Recommendations



The Figure makes two important points. First, the number of months to break-even in recommendations is generally very short. The longest for any measure is 20 months, meaning that, according to the projections of consultants, and without any discounting, investments in compressors can be totally recovered in less than two years from a reduction in energy bills. The months to break-even for other investment types are even lower, especially for measures based on maintenance and the like that have little up-front investment at all. Second, the range of measures covered is broad and appears to be related to the simplicity of measures as much as their returns. About 80% of plants have recommendations concerning lighting and motor sizing or efficiency. About 40% of plants have recommendations on insulation or heat recovery. These measures are relatively simple and "stand-alone." Other measures with comparable paybacks, such as automation (e.g. of boiler feeding and temperature control), may be less prevalent because they are more complex to implement.

Figure 4: Aggregate Projected Return on Detailed Energy Audit Recommendations

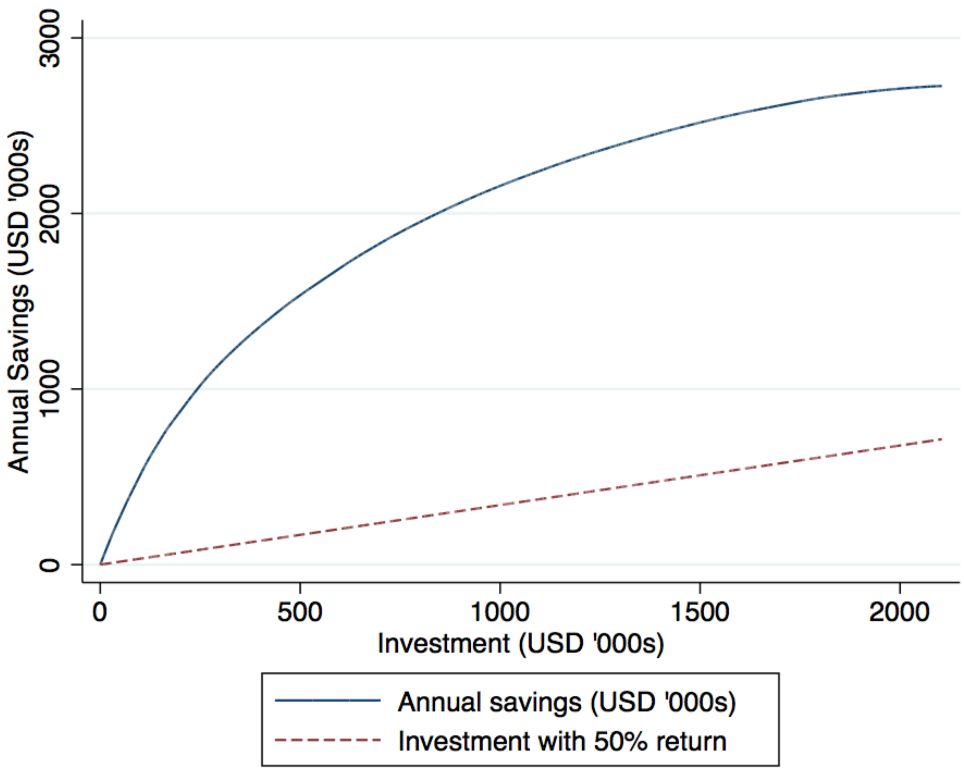


Figure 4 above summarizes the projected returns across all measures recommended and all plants. The horizontal axis is the amount of investment required and the vertical axis the projected annual savings in energy costs. The dashed line gives, for reference, the slope of an investment with a 50% annual return on this scale. Initial investments in energy efficiency, starting from the left, are projected to have very high returns, with the first $500,000 of investment yielding about $1.5m in annual savings. The projected returns then curve downwards fairly quickly and taper off after about $2m in investment.

The two Figures then give a coherent picture of measures recommended in energy audits. Such measures are numerous and have initially high returns but are limited in scope. The relevant questions for the experiment are then: How far along this curve of projected returns are plants actually willing to invest? How much energy do these investments actually save? The next section gives some preliminary answers to these questions.

C. Follow-on Technical Assistance

Number of follow-on technical assistance visits provided by auditors (after audit) (by test cohort/innovation)

Auditors in the program have completed follow-on field visits for 39 plants in the sample audited by USAID out of the total 44 plants assigned to the implementation treatment. Each visit is part of an ongoing implementation assistance relationship that involves the drafting of a plan for the adoption of measures suggested in energy audit reports and two rounds of reporting, over the course of several months, to J-PAL while the consultant works with the plant to pursue these measures.

Table 5: Implementation Treatment Status
For Units in USAID Audit Treatment Group

	Control	Treatment	Not assigned	Total
Treatment Assignment	44	44	12	100
Treatment Completed		39		39

Because the implementation assistance arm of the project is also randomized within those plants receiving audits, we typically aim for half of the audited plants in a given group to receive implementation assistance also. The rate of 39/100 here is somewhat lower than half, but accounts for the fact that some plants are not interested to implement audit recommendations, for example if the initial investments described in the report are too high.

D. Industrial Site Field Surveys

Milestone Component: 100 cumulative Industrial site field surveys completed.

To measure the effect of Energy Consultancy treatments on technology adoption and energy consumption, the project includes detailed Industrial Site Field Surveys (endline surveys) that measure both economic and technical outcomes. The 100 Industrial Site Field Surveys funded by USAID have been completed in the Vatva, Ankleshwar and Surat industrial areas. (Note that, because the Surveys include both treatment and control plants, the 100 units Surveyed overlap with but are not wholly the same as the 100 units treated with Energy Consultancy and described above.) With co-funding, we are continuing the survey through the rest of the sample, with an overall target of 400 plants.

The Surveys are unique in their hybrid scope, covering both technical and economic outcomes. On the technical side, these Surveys are being conducted with The Energy Resources Institute (TERI), New Delhi as a technical partner. TERI has a reputation as the leading non-governmental organization working in the energy sector in India, and in particular on energy issues in the Small- and Medium-Enterprise sector. As part of this survey, TERI engineers measure the energy consumption due to specific pieces of equipment in each plant and calculate the efficiency of various plant systems. J-PAL completes the economic portion of the survey on plant energy bills, inputs and outputs.

IMPORTANT DISCLAIMER ON RESULTS BELOW

The results below in Sections E and F are based on the endline survey data collected thus far with funding from US AID for 100 plants. The project has a total sample size and therefore survey scope of 400 plants and the balance of the surveys are ongoing, with a target completion date of 30 June. The experiment was designed to measure an 8% change in electricity use in a sample of 400 plants.

Therefore, because of the partial sample coverage, the results to date are extremely preliminary and subject to change. Most differences are not statistically significant as the sample is only partially complete and therefore under-sized for the effects of interest. All results below are subject to change and we offer only tentative interpretations of their meaning.

E. Total Energy Reduction

Total energy reduction after intervention of sample small- and medium-enterprises (by test cohort/innovation),

The first table of tentative results from the endline survey shows regressions of total energy use on treatment status. The energy data are from bills and estimates collected during the endline survey at the plant by month level. Electricity data are generally extremely reliable, as these are recorded directly off of the bills provided by the power company for every plant. Fuel use and billing data are somewhat less reliable, as the sources and quality of documentation differ by fuel source (e.g., bills for natural gas are very accurate, whereas records of coal or wood consumption may be inaccurate).

Table 6: Energy Consumption on Treatment

	(1) Monthly Electricity Demand (kWh)	(2) Monthly Electricity Bills (Rs)	(3) Monthly Electricity Energy Charges (Rs)	(4) Total fuel bill (Rs)
Audit treatment assignment (=1)	3146.6	38588.6	36704.7	78092.3
	(3625.6)	(26735.4)	(25908.3)	(137394.9)
Fuel bill, annual				0.0402***
				(0.0104)
Constant	68995.7***	427023.7***	414283.6***	207174.0***
	(2316.3)	(17152.1)	(16368.2)	(71514.6)
Observations	1225	1193	1193	355

Electricity regressions include dummy variables for baseline electricity consumption strata as controls.
Standard errors in parentheses clustered at the plant level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6 shows that the energy-audit treatment is associated with a positive but statistically insignificant *increase* in energy bills, both for electricity and fuel. In the first column, total electricity use increased by about 3,000 kWh per month, or 4.5% of control energy use (for benchmarking purposes, an average American home uses about 1,000 kWh a month, so this could be thought of as an increase of three U.S. homes). This increase is reflected in an increase in total electricity bills (column 2) and in particular in the energy or variable charge component of those bills (column 3). The increase in variable charges in column 3 has a p-value, the probability of finding such a positive result were the true effect actually zero, of 16%. Finally in column 4 the total fuel bill is also estimated to increase by Rs. 78,092, or 16% of the mean fuel bill of about Rs. 500,000 per month. (Note that the mean fuel and electricity bills are both around the same level, Rs. 500,000 or USD 10,000 per month).

Could such an increase be a legitimate effect of the audit treatment, which was intended to identify investments to save energy? Yes, it well could, and this hypothesis warrants further investigation. Energy-efficiency investments, by improving the efficiency of the plant, mean that a given energy input can produce more output. If the plant aims to produce the same output, energy use will fall with improved efficiency. However, improvements in efficiency may, in theory, induce newly more efficient plants to expand production via a positive use-elasticity or “rebound” effect. Empirical evidence on such an effect is relatively thin. One recent and rigorous study of consumer appliance use in Mexico has found that rebound effects caused the distribution of more efficient air conditioners to increase energy use (David, Fuchs and Gertler, “Cash for Coolers”, NBER Working Paper No. 18044, 2012). It is possible, and would be of enormous policy relevance, if such an effect were at work here for industrial plants.

F. Energy-Efficiency Investments

Firms undertaking energy-efficiency investments attributable to audit assessment and follow-on technical assistance (by test cohort/innovation)

Any effect of the treatment on energy use should come through that plant's investment in and operation of energy-using equipment. To investigate this channel, Table 7 presents the impact of the treatment on investment in equipment upgrades and equipment operation. We find that the treatment has a positive but modest and statistically insignificant effect on investments in equipment. Treatment plants invest, on average, about Rs. 11,000 more in equipment and maintenance than control plants (because some upgrades may be classified as maintenance, the total is probably the most reliable measure of investment). These differences are estimated very imprecisely in the small sample and the treatment effects are not significantly different from zero. At the plant level, we also look at the reported hours of operation for each piece of equipment each month. Hours of operation increase by an estimated 23 hours (standard error 37 hours) per month, which is positive and statistically insignificant. The point estimate is a roughly 7.5 percent increase over the baseline hours of operation.

Table 7: Investment in Equipment by Treatment Status

	Treatment	Control	Difference
Equipment, cost of upgrade (Rs)	32392.3	28508.1	3884.2
	[83096.3]	[96561.3]	(15962.6)
Equipment, cost of maintenance (Rs)	15532.3	8236.1	7296.2
	[92424.8]	[24050.8]	(12113.1)
Equipment, operating hours per month	331.8	308.8	23.0
	[217.2]	[197.6]	(36.9)

* p lt 0.10, ** p lt 0.05, *** p lt 0.01

From aggregate investments and operation we can zoom further into the plant operations to see whether there is evidence consistent with improved plant efficiency. We have just begun this analysis and present overview tables of two of the most important plant systems, the boiler and related equipment and the electrical distribution system. The boiler is where fuel is consumed, in order to generate heat or steam used in the plant, and the electrical distribution system is where electricity reaches the plant and is distributed to various productive uses. These two systems are important for the efficiency of fuel and electricity consumption, respectively.

Table 8: Boiler Efficiency Features by Treatment Status

	Treatment	Control	Difference
Heat recovery system	0.38	0.37	0.013
	[0.40]	[0.35]	(0.070)
Steam traps	0.48	0.33	0.15**
	[0.38]	[0.29]	(0.063)
Combustion control	0.58	0.71	-0.12
	[0.47]	[0.43]	(0.084)
Insulation	0.90	0.88	0.011
	[0.26]	[0.30]	(0.052)
Feed water pump	0.67	0.70	-0.027
	[0.36]	[0.34]	(0.065)
ID/FD fans	0.89	0.87	0.021
	[0.28]	[0.32]	(0.055)
Observations			

* p lt 0.10, ** p lt 0.05, *** p lt 0.01

Tables 8 and 9 are a first look at the detailed components of these systems. In Table 8, we present the prevalence of various efficiency features by treatment status. Of six features presented, most are insignificant, but there is a large and statistically significant increase, of 15 percentage points or nearly 50%, in the use of steam traps in the treatment plants relative to the control. Steam traps remove water that has condensed as steam cools in its distribution around the plant. Installing and maintaining steam traps properly is an important way to reduce steam loss in distribution and therefore improve the overall efficiency of a plant's steam system. It is economically sensible that we would see movement on this investment but not others observed. Steam traps involved relatively modest investments and had low penetration, whereas other investments in boiler efficiency had either higher investment cost (e.g. heat recovery systems) or very high baseline penetration (e.g. insulation). Note that this table only covers whether a feature is present; we intend to investigate in further analysis the efficiency with which each feature is working.

Table 9 is a similar overview of the presence of various features in the electricity distribution system. Unlike the case of the boiler system, there is no single prominent effect of the treatment in terms of features installed. Treatment and control plants are similarly likely to use automatic voltage controllers , capacitor banks and electronic ballasts for lighting, for example. They also have similar power factors, a measure of how much electrical energy is put to effective use. However, there is a fairly large, but statistically insignificant, increase in contract demand for treatment plants of 33 kVA on a base of 158 kVA, about 20%. The contract demand represents how much the plant contracts with the electric utility to regularly draw in terms of electric load. If treatment plants did increase contract demand, this would be consistent with increases in energy use as observed in bills.

Table 9: Electrical Efficiency Features by Treatment Status

	Treatment	Control	Difference
Contract demand, current	191.1	157.7	33.3
	[183.6]	[150.4]	(30.8)
	[0.25]	[0.35]	(0.056)
Control, auto voltage (whether present=1)	0.083	0.10	-0.020
	[0.28]	[0.31]	(0.054)
Power factor	0.91	0.89	0.024
	[0.16]	[0.16]	(0.030)
Capacitor bank (whether present=1)	0.87	0.91	-0.047
	[0.34]	[0.28]	(0.058)
Capacitor bank, rating (kVAR)	144.1	121.5	22.7
	[123.4]	[118.8]	(24.1)
Capacitor bank, power factor adjust, type (automatic=1)	0.76	0.70	0.063
	[0.43]	[0.46]	(0.090)
Lighting, electronic ballasts (present=1)	0.54	0.51	0.024
	[0.50]	[0.51]	(0.11)

* p lt 0.10, ** p lt 0.05, *** p lt 0.01

In summary, the evidence to date on energy-efficiency investments supports the idea of treatment plants making some modest investments in energy-efficient equipment, relative to control. The best estimate is that these investments total only Rs. 11,000 per plant, and a statistically significant change is the increase in the use of steam traps in the treatment. There is also some economically significant but statistically weak evidence of an increase in contract demand.

G. Role of Additional Data Collection

The pattern of preliminary changes support the hypothesis that the treatment did induce efficiency investments but led to increases in capacity utilization and hence energy use. It is too soon to put this conclusion on solid ground but it will be an important hypothesis to test as we collect additional survey data from sample plants. Additional survey data will test these findings by adding increased statistical power, allowing measures of treatment heterogeneity and allowing tracking of firms over a longer time period.

The primary benefit of additional data is increased statistical power. The findings regarding increases in energy use above are based on preliminary and incomplete data—they do not cover the full study sample. This lack of coverage means that what effects we measure do not have much statistical power. For example, the about 9% increase in electricity bills in Table 6, column

(2) is not statistically significant at conventional levels, but if the point estimate remained constants, this effect would likely be highly significant in the full sample. We will also be able to get more power for ancillary outcomes such as output and sales, which are typically less well measured than electricity use and therefore require a larger sample for meaningful analysis.

A separate concern is that the survey sample so far may be imbalanced between the treatment and control groups. This is minimized by the fact that the regressions control for baseline energy consumption and by the survey being designed to proceed in a balanced fashion across both groups. Still, the composition of the chemical and textile factories surveyed to date is not exactly the same as the composition of these plants in the whole sample, so the results may change as more plants are surveyed—due both to different true effects of the treatments and to random noise. With the full sample, we will be able to investigate whether the estimated treatment effects differ by baseline characteristics of firms, and in particular by the projected returns to efficiency found in energy audits.

Additional data collection will also give the energy consumption data a longer time dimension. At the time of endline surveys we request plants to sign a consent form for the local electric utility to grant us access to their electricity bills in the future. We then can return to the utility to get electricity bills following long after the treatment. It will be interesting to watch how the patterns of energy consumption evolve. If, in fact, the treatments induce firms to become more efficient and gain market share, we may expect that this effect would grow over time.

Finally, we plan to include some qualitative interviews with plant owners in the next survey rounds. These will allow us to better understand the reasons behind adoption decisions. We also find that such case studies can be a persuasive complement to statistical analysis for policy-makers.

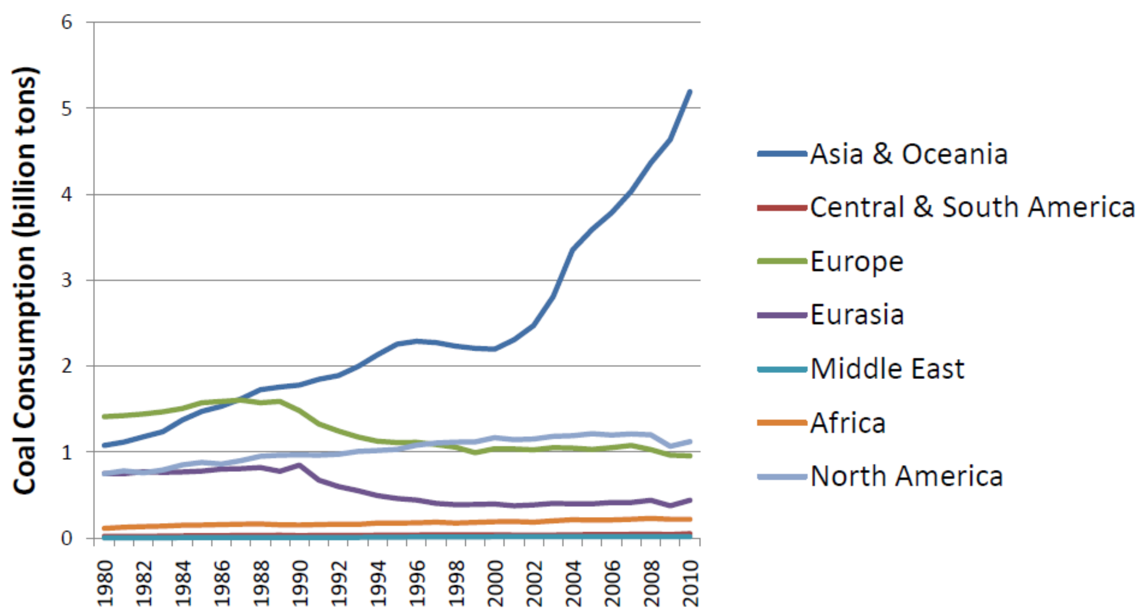
4. Scaling Plan and Policy Dissemination Report

A. Context for Scaling of Energy-Efficiency Investment

Energy-efficiency is of policy interest at the international, national and local levels. Before describing the scaling and policy dissemination plans it is important to understand the reasons and institutions behind large-scale investment in energy-efficiency as policy.

At the international level, interest in energy-efficiency is driven by its potential to reduce greenhouse gas emissions in the face of rapid economic growth. The baseline growth in emissions from developing countries is plain from Figure 5 below, which shows coal consumption by region of the world over time. Until about 2000, growth in consumption of coal, an important source of carbon dioxide emissions, was modest in Asia and negative in most other regions. Since then, economic growth in India and China has led coal consumption sharply higher, from around 2 billion tons to over 5 billion tons in the course of a decade. Today coal consumption accounts for 43% of global carbon emissions.

Figure 5. Coal Consumption by Region of the World



There are two basic ways to check this growth in emissions—generate energy from cleaner sources, such as solar or wind power, or use less energy per unit of output. The first option will play an important role in mitigation but is expensive and limited in scope; hence developing countries continue to build new fossil-fuel generation plants. As to the second option, energy-efficiency, the head of the U.N. Climate Change Secretariat called energy efficiency “the most promising means to reduce greenhouse gases in the short term.” The planned $100 billion/year Green Climate Fund aims to support a piecemeal approach to mitigation of climate change through technology transfer, including of energy-efficient technologies.

At the national level, the motivation for energy-efficiency is based partly on climate change mitigation but mostly on energy independence or self-sufficiency. India is a net importer of basically all fossil fuels, from oil and natural gas to coal. The prices of many of these fuels have risen and the government struggles to maintain subsidies on several important fuels. At the same time, about 300 million Indians do not have access to electricity and the demand for power, even among those connected to the grid, is often not met. Against these headwinds, the Indian Bureau of Energy Efficiency has National Mission on Enhanced Energy Efficiency across many sectors in order to reduce energy consumption and relieve the country's energy scarcity.

Finally, at the local level, the main concerns around energy-efficiency are a mirror image of national concerns. State utility companies in India generally do not have enough power to supply all their customers continuously, and institute rolling blackouts. Industrial and commercial activity is threatened by an unreliable energy supply. Because industrial and commercial customers often pay higher electricity rates to cross-subsidized agricultural and domestic consumption, these customers have a strong private motivation to invest in energy-efficiency to save money on electricity bills.

B. Scaling Plan

With this context in mind we present a plan to scale the results of this intervention. Because the agencies working to promote energy-efficiency at scale and those that make energy policy are often one and the same, the distinction between scaling and policy is not crisp. We therefore take "scaling" narrowly to mean the application of these findings to energy-efficiency in industrial plants in Gujarat, and "policy dissemination" to be using these findings to influence either the design or implementation of energy-efficiency policy at a national or international level.

The scale-up work will be conducted by both Principal Investigators and J-PAL's managerial staff and dedicated policy group, formed in order to reach out to policy-makers with experimental results. In South Asia, key staff for this effort include Deputy Director John Floretta, Senior Research Manager Vipin Awatramani and Policy Manager Shailesh Rai, who have all been developing expertise in energy and environment and contacts with policy-makers in the various states where we work.

The state of Gujarat, with tens of thousands of industrial plants, is an important setting for industrial energy-efficiency. In the two sectors covered by this study, chemicals and textiles, Gujarat has over 4,000 and 15,000 plants, respectively. Over 2,000 of these plants across both sectors are in the industrial areas of Ankleshwar, Surat, Vatva and Narol covered by this study. The local scaling plan has several different arms to reach out to these plants with information about energy-efficiency.

Direct Feedback to Industry. The project has been undertaken in partnership with industry associations. For every surveyed plant, we will provide feedback to the plant itself and, in an anonymous fashion, to the association, benchmarking plant performance against sectoral peers and suggesting opportunities for improvement, as estimated by the treatment effects. The combined membership of the associations engaged in the program is in the several thousands.

The information in Detailed Energy Audits, as seen in our preliminary results, does not appear to have been powerful in inducing industrial plants to take-up energy-efficiency investments. [TK] The nature of this information, engineering projections of expected energy savings, may not be credible or otherwise a sound basis for action for small enterprises. Information may be more helpful if set within a frame of reference for benchmarking one's own energy-efficiency against the performance of peer plants.

Therefore, to test this hypothesis and use the data from the endline survey on a broad scale, we are designing an informational feedback intervention. This intervention will provide information on where each given plant falls in the distribution of plant efficiency and why—e.g. greater or lower motor efficiency, insulation, boiler efficiency, etc. The main indicators of interest will be output in units of kilograms (chemical sector) and meters (of cloth, in textile sector) per unit of electricity and fuel input. These variables will be presented relative to the same measures for other, peer plants in the same sector, in order that each plant can judge its relative performance with respect to energy-efficiency.

Gujarat Energy Development Agency. Gujarat Energy Development Agency (GEDA) is a part of the Government of Gujarat and is responsible for renewable energy and energy-efficiency programs in the state. GEDA has provided a partial subsidy of INR 20,000 (about USD 400) to plants for energy audits conducted as part of this study. This subsidy reduced the cost to the researchers, and therefore funders, of conducting the study and gives GEDA a stake in the study's results. We have given GEDA an interim report on the findings of Detailed Energy Audits and will update this into a final report after the endline survey is complete. We intend that these reports and our discussion would suggest how GEDA could design its industrial energy-efficiency programs for Gujarat. Large plants are presently required to hire energy consultants to review plant performance every three years. GEDA and the office of the Industries Commissioner both work to encourage energy audits for small plants.

A second channel for scaling is the consultants that GEDA certifies as energy auditors for the state. We worked with eight of these consultants in the study and there are between 30 and 40 certified in all. We have preliminarily discussed with GEDA the idea of holding a conference to discuss lessons and findings from this study with all the energy consultants together, and will plan this conference for sometime in Q2 2013 as the survey concludes.

Gujarat Pollution Control Board. In other research, we have collaborated with the Gujarat Pollution Control Board (GPCB) to study environmental regulation. The GPCB is concerned with plant efficiency from the point of view of minimizing input consumption and output pollution, in particular water and fuel consumption. This goal overlaps with energy-efficiency to some extent as energy-efficient plants will generally use less fuel, water and other inputs, generating less air and water pollution. We will present the results of this study at GPCB, which has an ongoing process-efficiency program for the textiles sector.

Utilities. A second channel at the state level through which the study might affect energy use is working with electric power utilities. We have agreed to collect some energy use data centrally from the power company in order to monitor plant energy use over time. Utilities presently encourage conservation through non-linear electricity tariffs that reward some aspects of efficiency, like accurately predicting one's electricity load. The results of the study may help utilities set optimal charges to promote efficiency in electricity use.

C. Policy Dissemination

Energy-efficiency has lately become a huge focal area for national energy policy in India, which gives this research a natural audience in the organizations that are working on industrial energy-efficiency programs of their own. The Government of India in 2001 enacted an Energy Conservation Act to "provide for the efficient use of energy and its conservation." This Act established a national Bureau of Energy-Efficiency, which subsequently launched a National Mission for Enhanced Energy Efficiency to promote energy conservation across all sectors, including not only industry but also domestic and commercial consumption.

Table 10 on the following page summarizes the biggest efforts for industrial energy-efficiency in small- and medium-enterprises. International donors, including US AID, the World Bank, JICA and KfW have joined the Government's efforts in this sector through several projects at a national scale. These projects have various components but two are most prominently featured. First, detailed or walk-through energy audits, as used in the primary treatment in this study. Second, subsidized financing for energy-efficiency investment. The close link between this study design and recent policy in this area mean that the findings of the study will merit attention at the organizations mentioned, in particular the BEE, TERI, JICA and the World Bank. After the table we describe our plan to disseminate findings to these groups.

Table 10: Major Energy-Efficiency Projects in India

Project	Dates	Agencies	Activity	Scope
World Bank – Global Environment Facility	2012 – 2013	Bureau of Energy Efficiency (BEE), Small Industries Development Bank of India (SIDBI)	Detailed energy audits, capacity building	Ankleshwar, Faridabad, Kolhapur, Pune, Tirunelveli
BEE Small- and Medium-Enterprise (SME) Program	2010 – 2011	BEE	Detailed energy audits, technology identification, capacity building	Over 4,000 units in 35 clusters across India
SIDBI Financing Scheme for Micro, Small and Medium Enterprises	2008 - 2010 (Phase I), 2011	SIDBI, Japanese International Cooperation Agency (JICA)	Financing for SME energy-efficiency through $330m subsidized loan	MSME units from all India, minimum investment grade rating from SIDBI and 10% energy saving potential (Phase II)
Financing Energy Efficiency Projects in the MSME Sector	2012 -	KfW Group, SIDBI	Financing for SME energy-efficiency through $70m subsidized loan	MSME units from all India, minimum investment grade rating from SIDBI
Energy Conservation and Commercialization (ECO) Project, Phase III	2006-2009	US AID, BEE	Feasibility studies, technology development, select investment-grade energy audits	Four SME clusters including Ludhiana, Ahmedabad, Mandi Gobindgarh

At the national level the scaling strategy focuses on working with the Bureau of Energy Efficiency to institutionalize the lessons of the research. The BEE, as is evident from the table, is the nodal agency for most national-scale work on energy-efficiency in India. We solicited the advice of the BEE at the early stages of this project and selected the Chemicals and Textiles sectors for study after consulting with prior BEE data and reports. We will present the findings of the study to the Director and concerned Energy Economists at the BEE.

The Energy and Resources Institute (TERI), our survey partner, is a non-governmental agency but still important for energy policy in India. TERI runs a website for small- and medium-enterprise energy efficiency called Sameeeksha (http://sameeeksha.org/) to share knowledge about energy-efficiency with industry. This platform is a joint venture of TERI, the BEE, the Climate Change and Development Division of the Embassy of Switzerland and the Ministry of Micro, Small and Medium Enterprises. We published a progress report on this study in a issue of the Sameeeksha newsletter in 2012 and will publish an update and present the findings to the Sameeeksha Core Committee once they are final.

Findings on the true returns to energy-efficient technologies and the best way to promote their adoption will be relevant not only within India but also globally. The U.S. is currently promoting a piecemeal policy of subsidies for renewable-energy and energy-efficiency. This experiment will measure how the characteristics of technologies affect their adoption and the energy-savings they achieve and in this way can inform how governments could effectively go about tilting the energy playing field to promote sustainable energy use. At the international scale, one of the largest greenhouse-gas abatement initiatives to date is the Green Climate Fund, a proposed $100 billion transfer from developed to developing countries for use in technology development, abatement and adaptation. This experiment can provide evidence on what kind of technologies work to raise efficiency for industry and the manner of delivery that can get these technologies adopted.

he acting director of the Green Climate Fund is Dr. Ajay Mathur, former Director General of the Indian BEE. We interacted with Dr. Mathur briefly when he was at the BEE and will aim to bring the findings to his attention in his new role by presenting the findings at the Green Climate Fund. The research team has also opened the channel to energy policy at the global level by partnering with The Energy and Resources Institute (TERI) to conduct the end-line survey of technology adoption and energy use. TERI is the most respected energy research organization in India, with activities spanning from the ground level of technology development to the international policy stage. TERI's Director General, R K Pachauri, is also the chair of the Intergovernmental Panel on Climate Change. We will present and discuss the results with partners at TERI to bring them to the attention of policy-makers working on climate change mitigation.

D. Preliminary Policy Messages on Efficiency and Cost Effectiveness

The pattern of preliminary estimates support the hypothesis that the treatment did induce efficiency investments but led to increases in capacity utilization and hence energy use. It is too soon to put this conclusion on solid enough ground to reach out to policy-makers. Nonetheless, it may be informative to sketch out, in very preliminary fashion, the types of policy messages that may emerge.

1. *Energy-efficiency policy may `rebound' to offset reductions in energy use for individual plants*. If the primary goal of policy is to reduce energy use / carbon emissions, subsidizing information or efficient technology may therefore not be advisable. If the primary goal of policy is technology upgradation or competitiveness, then these policy tools may be more appropriate. This recommndation would be relevant to, for example, the BEE as it considers the merits of different efficiency instruments for industry. It would also be relevant in the broader climate policy community when considering substitute policy instruments in the absence of carbon pricing.

2. *Nonetheless, the wide-scale effects of energy-audits may reduce consumption in the economy.* If more efficient firms capture market share at the expense of less efficient firms, then energy-audits may reduce overall energy consumption even as they increase consumption for firms audited. This is an example of a beneficial spillover

effect. In this light energy-efficiency should be viewed as an important part of firm competitiveness and schemes, such as the BEE's PAT scheme, should strive to be as comprehensive as possible within a given sector so as not to advantage or disadvantage a subset of firms. For example, it may be correct for the PAT scheme to focus only on those sectors, such as cement, comprised exclusively of large plants. This recommendation would be relevant to the BEE as well as Ministries, such as the Ministry of Micro, Small and Medium Enterprises and Ministry of Commerce and Industry, that focus on competitiveness and manufacturing policy.

3. *Certain cheaper technologies may be a focus for wide-scale dissemination.* Going by the example of steam traps and capacitor banks, it seems like the most promising technologies are (a) inexpensive as far as initial investment (b) have moderate levels of existing penetration (unlike, say, insulation, which has high penetration) (c) may be tested and scaled-up within an individual plant (d) may require some advanced knowledge as to their placement or design. This finding would be relevant to specific industries and ministries, such as the Ministry of Textiles, and may be best disseminated through industry associations and group meetings.

4. *Informational instruments like energy audits can work.* If the positive treatment effect on energy consumption holds up, this would be striking for the simple fact that it shows audits do tell firms something new. Independently of the actual effect of the policy, this shows that informational campaigns or tools may influence firm behavior as well as consumers'. This finding would be relevant for many of the parties above such as the BEE.

With respect to cost effectiveness, the primary lesson so far is that policy goals need to be clearly specified. If the goal of energy-efficiency policy is to serve as climate policy, then a key lesson is that subsidizing efficiency is *not* the same as taxing energy or carbon use. In particular, efficiency only uses less energy for a given level of output—and we would expect more efficient firms to expand output, at least somewhat. Energy audits and energy managers do not, from preliminary evidence, appear to be cost-effective in reducing carbon emissions, as they are estimated to increase energy use. A more direct approach to taxing carbon, such as a direct carbon tax or a tax on dirty fuels such as India's coal cess, would then be more appropriate as a climate policy instrument.

If the goal of energy-efficiency policy is instead to improve the efficiency, productivity or profitability of certain manufacturing sectors, especially at a small-scale, then a cost-effectiveness analysis would compare any additional profits accruing to treatment firms against the cost of audits and energy managers. This comparison is in principle straightforward, though it can be very difficult to measure profits in the SME sector, where plants are hesitant to share data. Additional survey data and analysis will help us to broaden our focus from energy savings only to the total impact of firm efficiency and profits. Estimates of the total impact of the treatment on efficiency and profits will then be essential to measure the total cost-effectiveness of this largely informational program.

The most relevant alternative instruments in this domain are (a) subsidized capital, such as through the Ministry of Textiles "Technology Upgradation Fund" (b) subsidized loans for technology, such as through the Small Industries Development Bank of India. These instruments are generally very costly and have the further disadvantages, relative to informational programs, that they invariably favor some firms over others and may distort investment incentives towards certain approved or shortlisted technologies. A comprehensive cost comparison would therefore include not only direct measures of energy savings but also acknowledgment of these distortions. For example, if the government funds a large investment (such as a boiler) that a plant would not have made by itself, even if fully informed, this may cause a net social loss even if it decreases energy use significantly. Further comparison of information- and capital-based programs is a great direction for future research.