Is There An Energy-Efficiency Gap?
Experimental Evidence from Indian Manufacturing Plants[*]

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Abstract

Climate policy pushes energy-efficiency investments as a means to reduce energy consumption, and thus greenhouse gas emissions, in developing countries. I report the results of a large field experiment among energy-intensive Indian manufacturing plants that offered information and skilled labor to encourage energy-efficiency investments and practices. Treatment plants invest small amounts in recommended energy-efficiency measures; increase physical efficiency for some systems; increase capacity utilization across the board; hire more skilled labor; and invest more in other capital improvements. This suite of changes looks like modernization—a shift towards higher-skill, more capital-intensive plant production. The net effect of modernization on both energy consumption and productivity are roughly zero, within the precision of my estimates. Plants that become more efficient run more, which offsets any savings in energy. Similarly, treatment plants are estimated to increase sales by a large (though statistically insignificant) twelve percent, an amount offset by the higher cost of their new input mix.

JEL Codes: O14, Q41, D24, L65, L67

1 Introduction

In the last two decades, coal consumption in India has tripled and in China quadrupled, while declining slightly in the United States and other developed countries (Energy Information Administration, 2016). In the decades to come, growth in energy consumption is forecast to be four times higher outside the OECD than within. Therefore, any plan to address global climate change, which is caused by the consumption of fossil fuels, must reduce or de-carbonize energy consumption in developing countries.

To move towards this goal, without setting binding emissions targets for poorer countries, recent climate agreements have focused on pushing climate goods as much as taxing bads.

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For example, the Copenhagen Accords set a target of USD 100 billion per year to flow from developed to developing countries for climate adaptation and investments in greenhouse gas mitigation, such as through energy-efficiency.

What will be the return on such investments? This paper studies the case of energy-efficiency among Indian manufacturing plants, using a randomized-controlled trial that offers information and skilled labor to encourage energy-efficiency investments and practices. Energy-efficiency investments have become a high priority for greenhouse gas mitigation, since a common view is that such investments have high returns not only socially but even privately. A recent head of the UN Climate Change Secretariat therefore proclaimed "Energy efficiency is the most promising means to reduce greenhouse gas emission in the short term" (Doyle, 2007)..

The experiment recruited a sample of over four hundred energy-intensive plants from the chemical and textile sectors in the Indian state of Gujarat. The stakes for these plants to save energy are high, as the average plant spends USD 200 thousand on electricity and fuel each year, about twenty percent of total costs. The study worked with the Department of Climate Change, Govt. of Gujarat, to identify leading energy consultants in the state and enlist them to offer free energy consulting services to a random subset of these plants.

With the goal of giving a big push to energy-efficiency, the services offered were of two kinds. First, a random half of plants were offered information, in the form of detailed energy audits, a several-day review of specific energy consumption in the plant that looks for profitable investments to reduce energy bills. The output of this review is an energy audit report, presented to the owner or plant manager, that proposes investment options and details the required capital and projected energy savings for each option. Energy audits offered in this experiment were subsidized by the state under a program that predated the study. Second, a random half of those plants completing energy audits were offered skill, in the form of energy managers, engineer-consultants who would visit the plant periodically after the audit to encourage adoption of its recommendations, look after the procurement and installation of more efficient equipment, and advise plant staff on operating practices.

I collect data from a number of sources to cover possible plant responses to this efficiency push. First, a brief baseline survey was conducted to collect plant characteristics such as energy consumption and sales and decide eligibility to enter the sample. Second, from the audits themselves, process data on the measures recommended in energy audits in the treatment group and their projected returns. Third, an endline survey, conducted independently of the initial consultants, at least twelve months after the initial audit. The endline had two parts. A general part covered plant inputs and outputs at an aggregate level, with questions asked of the plant owner or manager, in a way similar to the Indian Annual Survey of Industries or other manufacturing surveys. A technical part, conducted on the plant floor by a team of engineers, measured the take-up of energy-efficient investments and the physical efficiency of plants. This part allows us to gauge the physical efficiency of plants, apart from data on projected savings and energy consumption. Fourth and finally, with plant consents, I collect electricity bills directly from the electric utilities that serve sample plants.

Gathering this diverse set of data is important, since the theoretical response to improvements in energy-efficiency is ambiguous on important dimensions like the amount, and even sign, of energy savings. Section 2 below describes these responses. In the short-term, if a plant's demand for energy services is held constant, we expect that improvements in efficiency will decrease energy demand one-for-one. In the medium-term, however, both input demands and the level of output may change. As a plant becomes more efficient, it will shift its input mix towards energy, unless factors are perfect complements in production. It will also buy more of input factors that are complementary to energy services to expand output. Both of these effects will tend to offset the direct energy savings from efficiency; it is entirely possible for higher efficiency to raise, not lower, energy demand.

I find that energy audits cause small amounts of investment in the efficiency measures they recommend, but nonetheless have large effects on plant production, by inducing plants to shift their input mix towards more high-skill, capital-intensive production and increase capacity utilization. The net effect of audits on energy consumption is therefore zero, within the statistical power of the study. To understand these findings we go through each step of the plant response in turn.

First, audits project high returns to energy-efficiency investment, but take-up of these measures is low. The median projected annual return on recommended measures in audits is 104%. The investments required for these measures are generally small; 95% of individual measures require investment of less than 1.7 percent of plant capital stock.[1] The total scope of

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[1] All monetary values in the paper were originally in Indian rupees and have been coverted to dollars at an exchange rate of USD 1 = INR 45.

investment is also limited, with the investment required to adopt all recommendations totaling less than three percent of baseline capital stock, however, because returns are projected to be so high, this degree of investment is forecast to save 11% of plant energy bills. Despite these high projected returns, plants assigned to the energy audit treatment are estimated to invest a modest and statistically insignificant USD 368 (standard error 256, p-value 0.15 against the null of zero additional investment) more in energy-saving equipment upgrades and maintenance. These effects on investment are larger for plants that are projected to have higher returns (lower payback periods for their initial investment) and are concentrated among a few plants that make large investments.[2]

Second, in the endline survey's direct meaures of efficiency, energy audit treatment plants are found to be insignificantly more efficient overall but measurably more efficient in some important plant systems. The survey encompassed a large number of efficiency measures from different areas of the plant. We aggregate these into a single efficiency index and find that treatment plants are 0.085 standard deviations (standard error 0.065 standard deviations) more efficient than control plants, but, for the boiler system, perhaps the most important single determinant of energy consumption, are a significant 0.287 standard deviations (standard error 0.166) more efficient. Treatment plants increase capacity utilization by a statistically significant one hour per day on a base of 17 hours per day in the control. Most plants are running at less than capacity; this evidence suggests that increases in efficiency due to energy audits led to increases in capacity utilization.

Third, how can firms have become more efficient, if they invested so little in energy-efficiency measures? I use the endline survey and energy bills to examine changes in the composition of inputs in response to the treatments. The audit treatment causes plants to hire economically and significantly more high-skill labor, on their own accord and apart from the consultancy services offered, by the time of the endline. Treatment plants hire more managers and more technical staff and see their total wage payments for these high-skill categories increase by USD 20 thousand per year (standard error USD 8 thousand), on a base of USD 28 thousand, far larger than the skill input in the original audit. By contrast, the treatment effect on low-skill labor is close to zero and insignificant. At the same time as they move towards high-skill labor, treatment plants also report a significantly higher market value

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[2] Using quantile regression, the treatment effect at the 95th-quantile is estimated to be far larger USD 72 thousand (p-value 0.07 against the hypothesis of no change in investment).

of their total capital stock.

Fourth, what is the net effect of these changes on energy consumption, which, after all, drives the externality of greenhouse gas emissions? Plants burn fuel directly and indirectly, by consuming electricity from the grid. The best measure of energy consumption is electricity consumption, because electricity is metered by and data obtained from electric utilities. I find that electricity consumption does not significantly decline in the energy audit treatment group relative to the control group. Electricity consumption appears to decline in the months after an energy audit, but I estimate that on average, over the first year, electricity consumption declines an insigificant 2,103 kWh per month (standard error 2,436 kWh per month), or 3.7% on a control mean of nearly 57,000 kWh per month. In the second year after energy audit, electricity demand is estimated to be flat in the treatment group, relative to the control. Including direct fuel consumption, these estimates become much noisier, for a lack of panel data, and the point estimate is that energy consumption actually increased in the treatment.

The overall pattern of the findings is thus that treatment plants invest small amounts in recommended energy-efficiency measures; increase physical efficiency for some systems; increase capacity utilization across the board; hire more skilled labor; and invest more in other capital improvements. I refer to this suite of changes as a modernization of plant production—a shift towards higher-skill, more capital-intensive production, at the margin.

Does modernization increase productivity? Treatmentx plants also see a positive and fairly large but significantly insignificant increase in output. To approximate the change in overall productivity, we do a back-of-the-envelope calculation using a Cobb-Douglas production function to calculate index-number productivity. The inputs that increased the most, high-skill labor and capital, have relatively small cost shares, so the overall share-weighted increase in input costs is comparable to the increase in output. That is, productivity is roughly unchanged in treatment plants.

What are the returns to energy-efficiency investment? If a policy-maker is narrowly interested in greenhouse gas emissions and therefore energy consumption, the returns to the promotion of energy-efficiency appear low. Treatment plants saved little energy, relative to projections, and then returned to control levels of consumption. If, more generally, the social evaluation of investment programs includes modernization, as defined here, as beneficial, then returns that include changes in plant productivity and profits may be higher. However, my (rather noisy) point estimates are that plants that modernize their input mix in response to audits and increase capacity utilization only break even.

The findings relate to two very active literatures, on the returns to energy-efficiency and on the productivity of manufacturing in developing countries.

In energy economics, the idea of an energy-efficiency gap between high projected returns and low rates of technology adoption has a long history but, until recently, had little clear evidence on either side.[3] Recent research has begun to credibly measure the returns to energy-efficiency investment and has generally found that energy savings due to efficiency investments may be overstated.[4] This paper is the one of few experimental studies in the literature and, to my knowledge, the only causal study of energy-efficiency investment by firms.[5] The phenomenon of "rebound," or the use-elasticity of energy services in response to efficiency, is well understood for consumers and has been estimated to be large in some cases (Borenstein, 2015; Davis, Fuchs and Gertler, 2014). The current paper gives a rich view of what rebound looks like for firms, which produce in competitive markets with multiple input factors, in an important developing-country setting.

On the productivity of developing-country manufacturing firms, there are apparently large differences between the productivities of developing-country firms competing in the same industries, and more productive firms, which should displace their rivals, instead grow at a sluggish pace (Hsieh and Klenow, 2009, 2014). In one view, these differences may be due to market failures that distort the allocation of inputs across firms. For example, Bloom et al. (2013), the closest antecedent to this study, argue that firms do not adopt profitable changes in management practices because of informational barriers.[6] In a more classical view, these

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[3] Early studies showed that moderate or high discount rates were needed to justify observed choices of efficiency (Hausman, 1979; Train, 1985), without attributing these estimates to market failures. Later work emphasized market-failure based explanations for a gap(Jaffe and Stavins, 1994). This idea has been taken up to support an active policy stance of energy-efficiency subsidies and mandates, but credible evidence that market failures contribute to any gap remains thin (Metcalf and Hassett, 1999; Allcott and Greenstone, 2012).

[4] (Davis, Fuchs and Gertler, 2014) find that energy savings from more efficient residential appliances are far less than projected, due in part to more intensive consumer use of more efficient appliances, which we expect would benefit consumers. Fowlie, Greenstone and Wolfram (2015) find negative returns for residential weatherization investments in Michigan due to lower-than-projected energy savings. Jacobsen and Kotchen (2013), to the contrary, finds that projected and realized energy savings for building code modifications in Florida line up well.

[5] Anderson and Newell (2004) study industrial energy audits by the U.S. Department of Energy's Industrial Assessment Centers and find take-up of 53% of audit recommendations, but are not able to observe energy consumption or physical efficiency after audits, or to establish a counterfactual for adoption. Rohdin, Thollander and Solding (2007) report that Swedish foundris have greater trust in information provided by their association than in government-sponsored energy audits.

[6] Bloom et al. (2013) experimentally offer management consulting in a sample of large textile mills in India. They find large effects of this consulting on management practices, quality and productivity, and estimate that

differences may be due to measurement error, or may arise because firms are making optimal investment decisions in an economic environment that is more volatile or less competitive than that in developed countries.[7] My study goes some way to reconciling these divergent views, in that I find relatively large input responses to an energy consultancy intervention, but estimate that these responses, when viewed through the lens of multi-factor production function, did not increase productivity overall.[8]

The rest of the paper runs as follows. Section 2 models how plant energy use may respond to energy-efficiency improvements depending on the flexibility of other factors of production. Section 3 gives background on the setting for the study and the design of the experiment. Section 4 describes the empirical results, and Section 5 concludes by discussing the relevance of the findings for energy-efficiency policy.

2 Model of Plant Response to Energy-Efficiency

Consider a plant that produces physical output (e.g., meters of textile) with the constant elasticity of substitition production function $Q = [(A_X X)^\rho + (A_E E)^\rho]^{1/\rho}$, where X is a composite factor of production, including factors such as capital and labor, and E is energy consumption. Each factor has a factor-specific efficiency, so that A_E is energy-efficiency and $A_E E$ the input of energy services. The elasticity of substitution between E and X is $\sigma = \frac{1}{1-\rho}$.

Let the price of output be p, the price of energy p_E and the price of the composite factor be one. Assume that the plant faces a downward-sloping demand for its output $Q = Bp^{-\epsilon}$.[9] Then the plant's revenue-production function is

$$Y(X,E) \;=\; B^{1/\epsilon}\left[(A_X X)^\rho + (A_E E)^\rho)\right]^{\phi/\rho}.$$

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these effects increase profits, as imputed from physical productivity, by more than the cost of consulting, even in the first year of adoption.

[7] Asker, Collard-Wexler and Loecker (2014) argue that nearly all of the cross-country dispersion in productivity can be explained by a dynamic model where firms face capital adjustment costs and more variable productivity shocks. In the United States, (Syverson, 2004) argued that transport costs can explain the degree of competition and hence productivity dispersion in an oligopoly market; it is plausible that, with higher transport costs (Atkin and Donaldson, 2014), this effect would be greater in developing countries.

[8] In development economics this paper also contributes to a literature on using firm-level experiments, often via consulting or other informational interventions, to understand the constraints on micro-enterprise growth. This literature has shown mixed results for the effect of training or consulting on firm profits for micro-enterprises, with some interventions increasing, and others decreasing, average profits (Fischer and Karlan, 2015; Drexler, Fischer and Schoar, 2014; Karlan, Knight and Udry, 2012).

[9] This assumption is common, often with relatively high ϵ to represent competitive industries (Foster, Haltiwanger and Syverson, 2008; Allcott, Collard-Wexler and O'Connell, 2014).

Where $\phi = \frac{\epsilon-1}{\epsilon}, \epsilon > 0 \Rightarrow \phi < 1$, so that the production of revenue has decreasing returns to scale, and absolute input demands are well defined. Define the per-period profit function given efficiency A_E as

$$\Pi(A_E) = \max_{X,E} B^{1/\epsilon} \left[(A_X X)^\rho + (A_E E)^\rho)\right]^{\phi/\rho} - X - p_E E$$

What is meant by an energy-efficiency gap? Suppose that the plant first chooses efficiency and then produces with that efficiency thereafter, facing static demand in each period. In starting production plants can invest in efficiency using capital and skill, $A_E = f(K_E, H_E)$, where $f(\cdot,\cdot)$ is continuous, increasing and concave in both its arguments. The optimal choice of efficiency is governed by $A_E = f(K_E^*, H_E^*)$, where

$$(K_E^*, H_E^*) = \arg\max_{K_E, H_E} \frac{\Pi(A_E)}{1-\delta} - K_E p_K - H_E p_H.$$

We define an energy-efficiency gap with respect to capital and skill as

$$\frac{\frac{\partial \Pi(A_E)}{\partial A_E}\frac{\partial f}{\partial K_E}}{1-\delta} > p_K \qquad\qquad \frac{\frac{\partial \Pi(A_E)}{\partial A_E}\frac{\partial f}{\partial H_E}}{1-\delta} > p_H. \tag{1}$$

These conditions state that the present discounted value of the product of the marginal profits from efficiency and the marginal efficiency from investment in a factor that produces efficiency exceed the price of that factor. That is, a gap is defined as when improving the efficiency of one's plant increases profits more than it costs today. Whether a gap exists will therefore depend on the appropriate discount factor δ as well as the effect of efficiency on profits.

A simpler criteria to define a gap would be based on energy savings alone. Suppose that $p_E \frac{\partial f / \partial K_E}{1-\delta} > p_K$, meaning that the present value of energy savings is greater than the price of investment in capital needed to achieve those savings. This formulation is sufficient but not necessary for a gap, as defined in (1) above, since it assumes that no other factors of production adjust to energy-efficiency. If other inputs or output can adjust, then energy savings may be small or negative, even when a gap exists and investment in efficiency is worthwhile.

Consider the response of energy consumption to changes in energy-efficiency. First, suppose that energy services are fixed, $A_E E = \overline{S}$. Then $\log E = \log \overline{S} - \log A_E$ so that the elasticity of energy consumption with respect to efficiency is $\varepsilon_{E,A_E} = -1$. This case of no input adjustment is what energy audit projections assume; the change in profits with efficiency is equal to the price of energy inputs, since energy consumption moves inversely with efficiency. This is a reasonable case for small improvements of efficiency and in the short-run, where we may expect energy inputs to be flexible from day to day–such as via drawal from the electricity grid–but labor contracts, materials orders and certainly capital to adjust more slowly.

In the medium-run, suppose the quantity of production $Q = \overline{Q}$ is fixed but demand for other inputs is flexible. Then we may derive energy demand and calculate the elasticity of demand with respect to efficiency as

$$\varepsilon_{E,A_E}\big|_{Q=\overline{Q}} \quad = \quad -1 + \sigma \frac{p_e^{\sigma-1}\left(A_X/A_E\right)^{\sigma-1}}{p_e^{\sigma-1}\left(A_X/A_E\right)^{\sigma-1}+1}.$$

Note $\sigma \geq 0$ and the right-hand term is weakly positive, so that energy use is found to decrease less than in the short-run case, as the plant substitutes towards E consumption depending on the value of σ. In the case of Leontief production $\sigma = 0$ and efficiency again reduces energy consumption one-for-one; for *any* positive degree of substitution the energy savings will be muted.

Now consider a longer-run case where quantity $Q = Bp^{-\epsilon}$ can adjust. I derive the elasticity of energy demand with respect to efficiency as

$$\varepsilon_{E,A_E} \quad = \quad \varepsilon_{E,A_E}\big|_{Q=\overline{Q}} + \varepsilon \frac{1}{p_e^{\sigma-1}(A_X/A_E)^{\sigma-1}+1}.$$

Thus, in addition to the substitution effect present in the fixed-quantity case, energy consumption can additionally increase due to an expansion governed by the elasticity of demand $\epsilon > 0$. In some cases this could be large, such as for large ϵ but small σ, when the more-efficient plant can expand by offering a lower price but does so mainly with energy use, since inputs are not very substitutable.

What happens to the use of other inputs? The elasticity of X demand with respect to A_E is given by

$$\varepsilon_{X,A_E}\big|_{Q=\overline{Q}} \quad = \quad (\epsilon - \sigma)\frac{p_e^{1-\sigma}(A_X/A_E)^{1-\sigma}}{1+p_e^{1-\sigma}(A_X/A_E)^{1-\sigma}}.$$

We see that X demand increases, in response to a change in A_E, when output demand is elastic relative to the elasticity of substitution between inputs. If output demand is elastic but it is hard to substitute X and E, then an increase in A_E will mainly lead to an increase in X, to keep up with the greater use of energy services for each level of energy input.

There are several takeaways from this theory on plants' response to improved efficiency that will guide the empirical work. First, the correct measure of energy-efficiency gap is a comparison of change in profit to investment, not only the discounted value of energy consumption. Therefore the empirical analysis will encompass energy consumption but also other input responses to the experimental treatments.[10] Second, in the short run, prior to the response of other inputs, energy consumption is sufficient to measure the plant response to improvements in efficiency. The energy consumption response is expected to be largest in the short run since the input of energy services is roughly fixed. The effect on other productive factors will depend on whether they are complementary or substitutable with energy. Third, in the medium and longer runs greater efficiency will induce substitution towards energy service as an input and some expansion of production, which will offset the initial reduction in energy consumption to a degree that depends on the elasticities of substitution and demand. The sizes of these effects and the sign of the effect on energy consumption are ambiguous and depend on parameters.

3 Context and Experimental Design

(a) Energy-efficiency policy in India

Energy is a productive input of special importance from a policy view. From 2010 to 2040, energy use in non-OECD countries is projected to increase 90 percent, as compared to 17 percent in the OECD (Energy Information Administration, 2013). The industrial sector accounts for the largest share of energy demand and it is likely that 80% of energy use overall in 2040 will still come from fossil fuels. The combustion of these fuels causes large externalities through local air pollution that damages human health and greenhouse gas emissions that contribute to global climate change. Policy-makers have lately stressed the importance of

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[10] Actual or imputed profits are difficult to measure since many plants decline to disclose production data and raw material consumption, which are targets of environmental regulation. Bloom et al. (2013) also report not being able to obtain accounting measures of profit despite deep engagement with sample firms.

efficiency, or a reduction in energy demand, for climate change mitigation. The head of the U.N. Climate Change Secretariat recently hailed energy efficiency as "the most promising means to reduce greenhouse gases in the short term."[11]

The belief underlying this statement is that energy-efficiency is cheap: if market failures make plants use energy inefficiently to begin with, fixing these failures can both reduce carbon emissions and save enough money on energy bills to be profitable even privately (See Allcott and Greenstone, 2012, for a review of the evidence on this idea). If this is true, a small amount of public investment in information or subsidies to technology adoption could yield large returns in lower energy consumption. Energy policy has been shaped around this idea. The United Nations Framework Convention on Climate Change (UNFCCC) has founded a Green Climate Fund to send money from developed to developing countries partly for climate change mitigation measure like energy-efficiency. In India, the US Agency for International Development, the Japanese International Cooperation Agency and the German overseas aid agency KfW are all active in industrial energy efficiency, having supported energy audits, technology development or subsidized lending for technology adoption.

The Indian government itself places a high priority on energy-efficiency in manufacturing. The government imposes a modest coal tax of INR 50 (approximately USD 1) per ton to fund clean energy technology, but the primary policy instruments for energy efficiency are informational and capital subsidies. The Bureau of Energy Efficiency, Ministry of Power has launched a "National Mission on Enhanced Energy Efficiency" across many sectors. For industry, this mission includes both an energy-conservation credit trading system for very large plants, and, for smaller plants, a nationwide campaign of energy audits and capital subsidies to identify energy-efficient technologies and encourage their wide adoption. This experiment was undertaken jointly with the Gujarat Energy Development Agency (GEDA), Department of Climate Change, Government of Gujarat, which is the BEE's state partner agency in the state of Gujarat.

(b) Selection of sample plants

The sample of plants was drawn from industrial associations with members in the textile and chemical sectors in the Indian state of Gujarat, which is home to 5% of India's population but

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[11] Doyle2007

17% of industrial investment. In the chemical and textile processing sectors plants may spend 15-20% or more of their total production costs on energy. The Gujarat Energy Development Agency (GEDA), a state government body responsible for the promotion of energy-efficient and renewable energy technologies in Gujarat, reports technically feasible "savings potentials" of around 20% of total energy bills for small plants in many energy-intensive sectors, including these two (GEDA, 2009). A recent Bureau of Energy Efficiency (BEE) study found that small chemical plants in Gujarat with less than 200 tons of production each year use 4050 kCal of energy per kilogram of product, 22% more than the 3312 kCal used by large plants (BEE, 2010).

A target sample size of 400 industrial plants was set to detect an 8% drop in electricity consumption with 80% statistical power, based upon energy consumption data from a sample of energy audits carried out by the Bureau of Energy Efficiency (BEE) for chemical factories in Ahmedabad, Gujarat. To reach this sample size, randomly selected industrial association members were assigned to be solicited, by energy consultants, for their interest to receive free energy consultancy, possibly including a detailed energy audit. A total of 925 plants were contacted, of which 53% said they were interested. Appendix Table A1 lists the reasons why firms declined, which typically did not relate to energy use *per se*: only 4% of plants said they already had an energy consultant, 4% that energy was not a large cost for their plant, and a further 5% that they expected the scope of savings was not large. Most plants that gave a reason for declining cited concerns about data confidentiality. From the 490 plants that responded with interest, the sample was cut down to 435 based on a maximum threshold for electricity load, in order to limit the sample to smaller plants and reduce the variance of energy demand in the sample.[12]

What kind of plants decided to enter the sample? In order to understand sample selection, I collected administrative data on industrial registrations from the Industries Commissioner, Government of Gujarat. Registration data includes details such as the capital stock and employment of plants, but has several limitations: it is only available for plants that register, is typically out of date, and it may be distorted if plants do not report truthfully to the government. Appendix Table A2 compares plant characteristics, in the registration data, for plants that were interested in the experiment versus not, among the 206 solicited plants that

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[12] This restriction also has a policy motivation, in that most subsidized energy-audit programs restrict eligibility based on a maximum threshold for electricity load.

could be matched to this data set. The rate of interest is higher amongst these plants, at 75% instead of 53%, presumably because registered plants tend to be larger. Within the matched plants, most observable characteristics are similar, but interested plants tend to have a larger total capital stock, by USD 101 thousand (standard error USD 63 thousand). This difference is consistent with more capital-intensive plants selecting into the sample because they have more to gain from energy audits.

(c) Experimental treatments

The research design was a randomized-controlled trial with two intervention arms, meant to provide *information*, via plant energy audits, and *skill*, via energy managers. These treatments were chosen to test the leading hypotheses for why firms do not adopt energy-efficient technologies.

Energy audit treatment. A random half of treatment plants were offered free energy audits. An energy audit is a thorough, on-site review of how a plant uses energy and how it might profitably use less. Energy consultants employ electrical, chemical and mechanical engineers who spend approximately 6 man-days on site, depending on the size of the plant, collecting energy consumption information and measuring the efficiency of energy-using systems like motors, the boiler and the steam distribution system. At the conclusion of this measurement work, the consultant prepares an audit report suggesting investments to improve the efficiency of energy use, prioritized by their projected economic return. These reports are presented to the owner or plant manager of the audited plant in person, usually within two weeks of the completion of site work. As part of the experiment, the reports were also submitted to the research team and the Gujarat Energy Development Agency (GEDA), a co-sponsor, and both research and GEDA staff had the option to attend the presentation of reports.

Energy manager treatment. A random half of plants that completed energy audits and are interested in implementation are offered an energy manager to help in implementing audit recommendations. An energy manager is an engineer deputed to visit the plant for approximately 12 man-days over the course of several months, as decided jointly with the plant owner. This energy manager is responsible for identifying the most promising audit recommendations, procuring equipment, overseeing installation and training plant staff on any equipment or process changes.

The treatments were carried out by eight leading private energy consultants in the state of Gujarat and the neighboring state of Maharashtra. The Gujarat Energy Development Agency (GEDA) had a program to subsidize industrial energy audits that pre-dated this study. Under this program, plants using a GEDA-certified consultant could get a subsidy of 50% of the cost of audits, up to a cap of INR 20,000 (about USD 450), which typically bound. The energy consultants participating in the study were solicited from those certified in 2009 and 2010 by GEDA. GEDA certifies 30 to 40 consultants as able to conduct thermal and electrical energy audits, which allows consultants to participate in the subsidy program as well as other government-sponsored consultancy and training activities. The consultants working in the study were deliberately selected from this group to be high-performing: the research team vetted consultants, in person and with the recommendations of GEDA, and invited eight of the best to conduct the project treatments on the basis of their reputations and past energy audit portfolio.

These services were paid for with a combination of research funds and government subsidies under GEDA's subsidy program. The total rate varied by consultant and plant between USD 900 to USD 1450. This total payment included USD 450 paid by GEDA on completion of the audit report and plant electricity bills. Research funds paid the rest of the total in equal installments on the completion of site work and the submission of the audit report to the plant. For the energy manager treatment consultants were paid at a flat rate of USD 800 to USD 1000 for the energy manager treatment, in two installments on the submission of progress and final reports.[13] The progress report was submitted after an initial meeting with the plant owner or manager to set out priorities and the final report to record any installations or upgrades that were done.

Table 1 summarizes the experimental design and the implementation of the treatments. Panel A shows the design, which is partially cross-cutting, since assignment to the energy manager treatment is conditional on the energy audit treatment. From the sample of 435 plants, 219 were assigned to the energy audit treatment, stratified by their electricity contract demand[14]. Only plants that completed this treatment and expressed interest in implementation

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[13] This rate appears lower per man-day than energy audits because (a) energy audits involve additional off-site analysis work (b) energy audits require the use of measurement instruments (c) the scheduling for energy managers is more flexible and hence the opportunity cost of time lower.

[14] Industrial plants declare their estimated load in advance, to help the utility forecast demand, and contract

were eligible for the energy manager treatment. This left an eligible group of 164 firms, of which 83 were assigned to the energy manager treatment.

(d) Data

Data on sample plants comes from five sources, a brief baseline survey, the energy audit reports in the treatment group, an extensive endline survey on both economic and technical outcomes, utility data on electricity consumption and expenditure, and finally a post-endline price survey of output prices using anonymous wholesale traders.

The first data source is a baseline survey covering plant characteristics such as employment and capital as well as aggregate energy use and expenditure. This survey was conducted by energy consultants and research staff together, prior to treatment assignment and coincident with the offer to enter the study sample and possibly receive free energy consulting. At the time of the baseline, plant owners or managers, who signed and stamped the survey form to register their interest in energy consultancy services.

Second, energy audit reports provide additional data on current energy consumption and projected energy savings for treatment plants. In an energy audit, consultants break down aggregate energy use into different systems in the plant and record the efficiency of these systems. For example, consultants will measure the rate of fuel input and sources of heat loss for a boiler to calculate its thermal efficiency. Energy audit reports then project, based on such calculations, what amount of energy and money would be saved were the plant to modify its operating practices or invest in new equipment. The main data of interest in energy audit reports are the recommendations, which note the system to be upgraded, its current energy consumption, the investment required for any upgrade, the projected savings and the payback period (= annual savings / investment), or number of years until the investment is projected to recoup its costs. Some recommended measures are operating or maintenance tips that carry no direct capital cost.

The third data source is a detailed endline survey covering both economic and technical aspects of each plant. The economic part of the survey comprised office interviews led by research staff with the plant owner or manager that recorded employment, materials, energy and other inputs, collected fuel and electricity bills and asked about the use of energy consultancy

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demand is the load they have signed up for with the electric utility and recent investments around the plant in upgrades or maintenance of equipment.

The technical portion of the survey was designed to measure the efficiency of sample plants directly with physical measurements of all the main energy-using equipment found in these textile and chemical plants. This part of the survey was conducted by two energy consulting groups that employed mechanical and chemical engineers experienced in working on energy conservation with small- and medium-scale industrial plants. Thermal systems measured include the boiler, steam distribution system and process equipment, such as jet-dyeing machines or chemical reaction vessels, that are the end-users of the steam generated. Electrical systems include the plant-wide electricity distribution system as well as individual motors, air compressors and pumps that draw most of the plants' load. The survey included protocols for how to select the equipment to be measured out of the range of equipment in the plant, on the basis of fixed system characteristics or a random number table when many systems of the same type existed. Critically, this protocol did not reference the recommendations of plant energy audits in the treatment group, ensuring that the equipment selected for measurement would be comparable across the treatment and control groups of plants.

The fourth data source and primary outcome variable is electricity consumption records from the electric utilities that service sample plants. Plants were asked in the survey to give written consent for their utility to share data on their electricity consumption and expenditures. Though electricity represents only part of plant energy consumption, this administrative data provides the most accurate record of energy use available, since it is independently metered, reported on a monthly basis and available for all plants.

The fifth and final data source is a price survey conducted by wholesale textile traders to solicit output prices using an audit methodology designed to simulate a real order. Several wholesale traders were hired and given scripts for contacting select sample plants, from the textile sector only, with plant-appropriate orders for textiles in a certain quantity and with a set width, weight, color, pattern, etc. The traders recorded the price offered, after some haggling, then declined to place an order.[15]

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[15] In order to insulate traders from damage to their reputations, the plants were divided so that not too many orders would be canceled in succession and so traders would be reaching out to plants in a different area than they typically worked.

(e) Experimental balance and attrition

Table 2 compares treatment and control plants using baseline survey data. Column (1) gives mean values, standard deviations, and sample sizes for each variable for treatment plants, and column (2) the same statistics for the control. Column (3) reports differences estimated as the coefficient on energy audit treatment assignment in a regression of the baseline value of each variable on treatment assignment and strata fixed effects. While sample plants are mostly classed as small- and medium-enterprises, they are quite large operations. The average sample plant has 83 employees, sales of about USD 1.8 million and half a million dollars in capital.[16] Treatment and control firms are statistically balanced on these measures. Sample plants spend USD 84,000 on electricity and USD 112,000 on fuel in a year, or about 11% of sales. The audit treatment was stratified on these energy bills, so that treatment and control plants are tightly balanced on these variables at baseline. Plants use a variety of fuel sources, including lignite (low-grade brown coal, 30% of the sample) to coal (21%), diesel oil (13%) and natural gas (51%). The one significant difference noted between the treatment and control groups is that treatment plants are significantly less likely (8 percentage points on a base of 55% in the control, p-value < 0.10) to use natural gas. Fuel usage is not mutually exclusive, as plants may switch from one fuel to another.

There was some attrition in the endline survey but this is balanced across the treatment and control groups. The endline survey was conducted at least one year after the energy audit, and sometimes two years or more after the baseline survey, in order to allow time for plant to invest. Appendix Table A3 shows that 334 plants, 77% of the sample, completed the survey. A further 10% of plants had closed and 12% refused the survey, typically because the data collected was relatively more invasive than the data collected at baseline. Appendix Table A4 shows that the rate of survey completion does not significantly differ with energy audit treatment assignment. Thus the experimental sample was balanced at the time of the baseline and sample attrition does not appear to disturb this balance thereafter.

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[16] The Indian government defines small- and medium-enterprises (SMEs) as having capital stock less than INR 10 million and offers various subsidies to SMEs, which together create an incentive to understate capital investment. Employment and sales are probably more reliable measures of firm size in this context.

(f) Experimental compliance

Assignment to treatment induced large and significant differences in the likelihood that sample plants would complete an energy audit or and smaller but significant differences in the use of an energy manager. Table 1, Panel B compares the share of plants completing energy audits and receiving additional on-site technical consultancy in the control group (column 1) for each intervention to that in the treatment group (column 2). Energy audit treatment plants are 67 percentage points (standard error 3.5 pp) more likely to receive an energy audit, a difference that is highly significant. This difference is less than 100 percent since compliance in the treatment group was imperfect, with nearly 20 percent of plants not completing audits, and some control plants got audits themselves.

Energy manager treatment plants were 23 percentage points (standard error 6.4 pp) more likely to have an energy manager, or non-audit on-site technical consultancy. While this difference is highly significant, compliance with this treatment was fairly low, with only 35 percent of the 83 plants assigned an energy manager following through. In most of these cases, the reason for non-submission of the final report was lack of interest from the plant in pursuing energy audit recommendations.

The experiment therefore generated large and significant differences in the use of energy consultancy by treatment plants, though the energy manager treatment was relatively weak and may therefore produce imprecise estimates. The results below will be reported on an intent-to-treat basis to record the effect of treatment assignment with imperfect compliance. To interpret these results as treatment-on-treated effects for plants actually using consultancy, the relevant first-stage coefficients for energy audits and energy managers are 0.67 (multiply by 1.49) and 0.23 (multiply by 4.3), respectively.

4 Results

This section presents the results of the experiment, from the contents of the audits through to investment take-up, physical efficiency and finally input and output responses. As described in Section 2, we expect that the effects of efficiency on energy consumption would be greatest in the short-run, but may attenuate over time as other factors of production and output can adjust.

(a) Audit projections

A candidate energy-efficiency gap is typically identified by comparing high engineering projections for returns to actual take-up or energy investment decisions (Metcalf and Hassett, 1999; Fowlie, Greenstone and Wolfram, 2015); therefore it is important to first look at what returns to energy-efficiency investments are *projected* to be. I study this by studying individual energy-saving measures recommended in energy audits and comparing the projected investments and savings for these measures to the scale of sample plants.

Figure 1 shows the distribution of investment sizes for 1,959 measures recommended for 173 treatment plants that completed energy audits. The width of each bin is USD 200. The vast majority of measures recommended require small investments below USD 1,000. Comparing investments to the scale of plants (not shown in the figure), 95% (99%) of measures require investment of less than 1.7 percent (6.6 percent) of the capital stock of the plant for which the measure was suggested.

What are the returns on these modest investments projected to be? Energy audit reports recommend investments for specific systems or pieces of equipment around the plant. Table 3 shows the characteristics of investments by the system they concern; column 1 gives the share of plants with an investment in that category, column 2 gives the number of recommendations, conditional on having any, column 3 gives the mean required investment and median annual return on investment, in terms of energy bill savings, by the type of investment.[17] The measures are ordered by the share of plants for which they are recommended. The average measure from all categories costs USD 1249, the median cost is USD 361 and the median projected return on measures recommended in 104%. The most commonly recommended measures concern lighting, motors and insulation, since these systems are present in all plants and the upgrades required are small. The median returns for these measures are projected to be in the range from 94% to 175%. The highest returns are for maintenance and other investment categories, since many of these investments have minimal investments costs, though they may have associated labor costs that consultants do not account for in energy audits.

Figure 2 summarizes the projected investments and energy savings by aggregating them across the treatment plants that completed energy audits and scaling them to the size of the

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[17] The number of measures variable can be misleading as a sign of prevalence, since a single measure may involve the replacement of a large number of similar lights or motors.

average plant. All measures with any positive investment are placed in decreasing order of their projected returns. The horizontal axis then shows the cumulative investment required as a fraction of the capital stock of each sample plant to undertake these measures, and the vertical axis the cumulative projected savings in energy bills, were these measures undertaken.[18] The figure shows that returns to energy-efficiency investment are projected to be high but diminishing. An initial investment of one percent of plant capital stock is projected to save 7.6% of plant energy bills, whereas an additional investment of one percent is projected to save an additional 2.5% of energy bills. Banerjee and Duflo (2014) use variation in the eligibility for a directed lending program to find a marginal return to capital of 105% for medium-sized Indian firms. The figure shows that if sample firms used this return as a hurdle rate, investing in all measures projected to have a higher return, they would invest a little more than two percent of capital stock and save a little more than ten percent of energy bills. Note that the extent of measures recommended, which is at the choice of consultants, does not go far beyond this level. Consultants generally report that plants will not consider investments projected to have significantly lower returns.

Energy audit reports, therefore, show that returns to energy-efficiency investment are projected to be very high but diminishing, and that the size of recommended investments is generally small. The projected quantity of investment, under a reasonable benchmark for this context, may be less than 2% of plant capital stock.

(b) Investment in efficiency measures recommended by audits

The data collected covers investment in two ways. First, the technical component of the survey involves engineers touring the plant floor and itemizing efficiency investments along with the technical staff of the plant. This part of the survey records investments specifically in the set of audit measures commonly recommended to any sample plant, and the results of this part are reported in this subsection and that following. Second, the survey also asked plant owners or managers about the overall market value of capital stock. Results on this measure are reported below, with other productive inputs.

Table 4 regresses actual investment on treatment status for sample plants.[19] The columns

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[18] That is, $TotalInvestmentScaled = TotalInvestment/(MeanPlantCapital \times NumberOfPlants)$ and $TotalSavingsScaled = TotalSavings/(MeanPlantEnergyBill \times NumberOfPlants)$.

[19] Investment in energy-using equipment maintenance and upgrades is asked of plant managers or staff with reference to specific pieces of equipment for a period of January, 2011 through the time of the endline survey,

of the table show different categories of investment, in upgrades (changing a piece of equipment) or maintenance (maintaining or improving an already-existing piece of equipment). The rows show coefficients on the assignment to the two experimental treatments from the specification:

$$Investment = \beta_0 + \beta_1 EnergyAuditTreatment_i + \beta_2 EnergyManagerTreatment_i + \epsilon_i,$$

where the treatment variable represents assignment to treatment and the energy manager treatment coefficient is included in even-numbered columns.

The energy audit treatment assignment is estimated to increase investment by a modest and statistically insignificant USD 292 (column 1), which rises to USD 368 (standard error 256, p-value = 0.15 against the null of zero change in investment) when the energy manager treatment is included in the specification (column 2). This change in investment is not significant at conventional levels, though the estimated change is fairly precise and it is 48% of the base of USD 762 investment in the control. From the audit projections, we can consider an alternate hypothesis H_1 of investment equal to USD $6,981 =$ USD $10,419 \times 0.67$, which is the investment that would be undertaken with a 105% hurdle rate applied to projected returns, accounting for incomplete compliance in completion of energy audits. The table shows that this investment rule is easily rejected in the data (p-value < 0.01).

Why is the point estimate for investment negative in the energy manager treatment group? Unfortunately, due to low compliance in this group, estimates of the effect of the energy manager treatment are imprecise, so that this coefficient is not close to statistical significance and it is difficult to test alternative hypotheses regarding the effect of skill on energy consumption. Nonetheless, columns 4 and 5 attempt to provide evidence by separating investment into equipment upgrades and maintenance. The point estimate for the effect of implementation assignment on equipment upgrades is negative USD 395 (column 4) and the point estimate on equipment maintenace is positive USD 205 (column 6). Neither estimate is significantly different than zero, though in the model of column 6, testing that the coefficient on maintenance is equal to negative USD 395, the coefficient on upgrades in the model of column 4, yields a p-value of 0.12. This pattern is consistent with skilled labor, in these plants, being

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a mean time of 2.25 years.

substitutable for energy-saving capital; plants can get by longer doing just maintenance and not upgrades if they have an engineer available.

Most of the effect of the treatment on plant investment in energy-efficiency measures comes from a few plants investing far more in the treatment. Figure 4 shows quantile treatment effects for the energy audit treatment with investment as the dependent variable. The specification is

$$\mathcal{Q}_{Investment_i|X_i}(\tau) = \beta_1 EnergyAuditTreatment_i + \beta_2 EnergyManagerTreatment_i + \epsilon_i,$$

where $\mathcal{Q}(\tau)$ is the τ-quantile of the investment distribution conditional on treatment status. The coefficients $\beta_1(\tau)$ are reported in the figure. Most plants in both the treatment and control groups invest nothing in energy-efficiency, so quantile treatment effects up to $\tau = 0.35$ are exactly zero. Above this point in the distribution, quantile treatment effects fluctuate at a small and generally positive level until $\tau = 0.8$, at which point they turn upwards sharply. The estimated $\beta_1(\tau = 0.95) = \text{USD}72,500$ is far larger than the average treatment effects, though still narrowly statistically insignificant (p-value 0.12 against the hypothesis of no change in investment).

Are these effects on investment heterogeneous, in a way that suggests plants attend to the returns on energy-efficiency? Table 5 shows regressions of the plant-level sum of equipment-level investment in energy efficiency on plant characteristics and interactions of characteristics with treatment status. The plant characteristics in columns 1 through 3 are measured in the baseline survey for treatment and control plants: annual energy bills, electricity contract demand (the electricity load a plant is signed up for with the utility) and number of employees. The fourth column interacts treatment status with the mean payback period, in months, for investments recommended in energy audits under the treatment. Payback period is the ratio of the projected capital investment for a measure over the monthly energy savings and is commonly used as a way to present returns in energy audits.

The table suggests that plants are responsive to returns when considering energy-efficiency investments. In the first three columns, we see that plants that have higher annual energy bills, higher electricity demand or a greater number of employees invest more in energy-efficiency measures. For example, each thousand dollars of annual energy bills increases investment in efficiency measures by about one dollar (column 1, $p < 0.10$). However, the effect of the audit treatment does not vary with these baseline characteristics–plants with higher energy demand invest more in these measures on their own, but not differentially more in response to the experimental treatment. In column 4, we regress investment in efficiency measures on treatment and the interaction between treatment and projected payback periods. The interaction term is negative and significant: each one-month increase in the average payback period of investments decreases take-up by USD 20. Note that, because projected payback periods are only observed in audited treatment plants, the specification in column 4 cannot include a payback period main effect; therefore, it is possible that the interaction coefficient is picking up a common response, by both treatment and control plants, that they invest less in longer-payback measures, and not a true interaction effect unique to treatment plants.

(c) Plant efficiency

This section test for effects of the experimental treatments on plant efficiency. In the notation of the production model, the quantity of interest is $\partial f/\partial K_E$, the change in A_E with respect to additional investment.

The data collected in the endline survey provide remarkably detailed measures of plant efficiency, which are not typically available outside of a few sectors with high energy consumption and homogenous output. The primary difficulty in analysis is to construct an aggregate plant-level measure of efficiency to benchmark many possible small changes within the plant and avoid specification search. I construct an index by taking physical characteristics of each system (size, whether insulated, external temperature, etc.), identfying those that directly measure or are related to energy efficiency, standardizing these measures by substracting their mean and dividing by their standard deviation, and taking the system-level average. This creates an equipment-level efficiency z-score for physical efficiency. When aggregating these equipment measures to the plant level, I weight by the inverse of the number of each equipment type in the plant–so if a plant has one boiler and ten motors, for example, the boiler receives greater weight when measuring overall efficiency. Along with efficiency, I report results on the hours of use for each piece of equipment per day, which surveyors ask of plant staff and managers with respect to each piece of equipment.

The energy audit treatment has meaningful effects on plant efficiency for some systems.

Table 6 relates the coefficients from regressions of efficiency indices on treatment assignment. Either the index itself (column 1) or the hours of equipment use (column 2) is the dependent variable, and the different panels record specifications for all equipment (Panel A) or for important systems in the plant, such as the boiler (Panel B), separately. Overall there is a statistically insignificantincrease in the efficiency index, with a coefficient of 0.0848 standard deviations (standard error 0.065 standard deviations). The coefficient on the efficiency index is greater than positive 0.14 standard deviations for three of the four systems, however, with the boiler showing a positive and statistically significant 0.287 standard deviation (standard error 0.166 standard deviations) increase in the efficiency index.

The model predicts that plants should respond to greater energy-efficiency by using more energy, unless energy and other inputs are perfect complements. Notably, the hours of use for all equipment is also higher for treatment plants, by a positive and statistically significant 1.12 hours (standard error 0.49 hours, $p < 0.05$) per day, on a base of 16.7 hours per day in the control. This roughly 7 percent increase in capacity utilization is seen across all four systems, but is greatest for the boiler system, which also had the greatest treatment effect for efficiency. Because the plant is run as a unit, we expect there is complementarity between running different systems, and therefore it is not surprising that point estimates indicate an increase in hours even for systems, like motors, that did not themselves become more efficient.

The physical evidence here supports that treatment plants increase efficiency and increase capacity utilization in response.

(d) Energy consumption

Energy consumption is an important outcome for policy since the main goal of subsidized information or the promotion of energy-efficient capital is to reduce energy consumption and the externalities it causes. It is important to consider energy consumption as an outcome, indepedently of energy-efficiency, since the relation of energy use to investment and efficiency depends on the response of plant input demand to efficiency changes.

Electricity demand is the primary outcome for energy consumption, as explained in Section 3. Because electricity billing data is available monthly, and not only at the time of the endline survey, it is possible to estimate the effect of the treatment on electricity consumption by month relative to the timing of the treatment, like a difference-in-difference specification with randomized treatment assignment. I estimate the specification:

$$ElectricityDemand_{sitm} = \alpha_m + \alpha_s + \beta_t \times EnergyAuditTreatment_{si} + \varepsilon_{sit}.$$

The dependent variable is electricity demand (or electricity bills) for a plant i belonging to baseline electricity demand strata s in calendar year-month m (e.g., July 2013) and period t, where period is defined as $t = 0$ in the month the energy audit is conducted.[20] The strata control for pre-existing cross-sectional differences in electricity demand and the year-month dummies for seasonality and trends common to all plants. The coefficients of interest are the elements of the vector β_t, which give the treatment electricity demand relative to control in each period relative to the audit. Sample errors are clustered at the plant level to account for auto-correlation in energy consumption.

Figure 3 plots the coefficients β_t from this regression from six months prior to eighteen months after the energy audit site work. Since no period dummies are omitted, the period zero effect need not be zero by construction, but it is estimated to be very close to zero, showing the validity of the experimental design. In the year after energy audits treatment electricity consumption twice declines relative to the control group, and reaches relative lows in excess of 5,000 kWh below control consumption four and ten months after audit. However, from then onwards treatment consumption rises relative to the control and the treatment effect is estimated to be small, positive and statistically insignificant at a horizon of 18 months after energy audit.

Table 7 summarizes this time series by looking at the effect of energy audit treatment assignment on electricity demand (column 1) and bills (column 2) in the two years after audit. The first coefficient in column 1 shows that the effect of the energy audit treatment on monthly electricity demand is estimated to be negative 1,952 kWh (standard error 2,409 kWh), on an average monthly consumption of 56,716 kWh in the control.[21] These estimates are reasonably precise, in that one standard error represents four percent of baseline electricity consumption, whereas all measures in energy audits were projected to achieve energy savings of over 11% of energy bills if adopted. The second coefficient shows that the effect of the energy

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[20] For control plants, the month relative to audit is defined according to the timing of the audit for the treatment plant in the same strata.

[21] As a frame of reference, an average US residential customer consumes 10,908 kWh per year, so the mean plant consumption in sample is equivalent to 62 US households.

audit treatment in the second year is estimated to be of similar magnitude but opposite sign, at positive 2,249 kWh (standard error 3,871 kWh). The second column shows that these changes in electricity demand are mirrored in the electricity bill, which shows a small decline in energy charges in the first year and a small increase in the second year.

(e) Other input demands

The above subsections consider direct or short-term effects of energy-efficiency. As highlighted by the model, the overall effects of energy-efficiency may include changes in other input demands and outputs, depending on the complementarity between factors of production and the elasticity of output demand. In this section, we use responses to the endline survey at the plant level to see whether plants responded to audits on these margins.

Table **??** reports factors of production from the endline survey by treatment status. Sales, high-skill labor, low-skill labor, capital and materials are responses to questions, asked of the plant owner or manager, on the total value of those inputs used in the last complete fiscal year (2011-12). The capital value shown in the table is the estimated capital input rent, based on multiplying the survey answer for the plant's total market value of capital by an assumed capital rental rate of 0.15. The energy input is calculated based on the sum of fuel bills, from survey responses, and electricity consumption, from administrative data on utility bills, aggregated over the same period. Inputs and output are sensitive information to plants and were selectively reported; hence, the varying sample sizes for each input. Energy input has especially few observations, because it is shown in the table only for plants that reported both their electricity and fuel expenses, which was uncommon. The first two columns in the table show the means of each factor for the treatment and control groups, respectively, and the last column the difference in means across groups.

The table shows a modernization of the production process. The point estimate for sales shows treatment plants sales higher by an estimated USD 252 thousand (standard error USD 400 thousand), which is not close to being statistically significant. Physical measures of standardized output, which were collected independently, are also not significantly different but are of the same magnitude (12 percent increase; not reported in table). The more striking and significant changes are in the demand for factor inputs. Demand for high-skill labor increases by a large and statistically significant USD 21 thousand (standard error USD 8 thousand), on a base of only USD 28 thousand. Capital inputs are also estimated to increase, by a large and marginally statistically significant USD 50 thousand (standard error USD 28 thousand, $p < 0.10$). This increase in capital is far greater than the observed investment in energy-efficiency investments. There are at least two plausible explanations for the difference. First, it could be because plants invested mainly in other measures not commonly recommended in energy audits, like new process machinery, which were not itemized as potential efficiency investments. Second, investment in efficiency measures may be poorly measured, relative to aggregate investments—there is evidence for micro-enterprises that it is better for researchers to directly ask aggregates, like profits, than to ask for components and calculate aggregates (De Mel, McKenzie and Woodruff, 2009).

Are such large proportional increases in factor inputs plausible? If the view of energy audits is mainly as promoting efficiency investment, these changes in inputs appear quite large; however, energy audits are also supposed to offer advice on how plants should be run. We drill down into the employment figures to look at the evidence for a shift towards high-skill labor, which may be needed to carry out audit recommendations. Table 9 shows the composition of employment by treatment status in the endline survey. The survey asked the plant owner or manager about the total number of people employed in different categories as well as their total annual pay. Managers are "Management (at plant)" employees; technical staff are "Technical or supervisory (at shop floor, excluding management)" and workers are "Workers (laborers at shop floor)." The first two columns show the means and standard deviations of these variables by treatment status and the third shows the difference (treatment less control) and the standard error of this difference

In Table 9, there are meaningful and independently statistically significant increases in the number of managers (increase of 0.89 people, standard error 0.51 people), the total pay to managers (increase of USD 8.50 thousand, standard error USD 4.01 thousand), the number of technical staff (increase of 3.02 people, standard error 1.35 people) and the total pay to technical staff (USD 15 thousand, standard error USD 6.23 thousand). The overall increase in high-skill pay is the sum of the increase to these two categories. There is no increase in the number of workers, who are far more numerous to begin with and comprise most of the total wage bill to all skill levels. Thus the treatment induced a shift towards high-skill labor.

(f) Productivity

Treatment plants therefore produce with a different input mix, and run more efficiently and longer. The theory predicts that, along with substituting towards greater energy consumption, plants will also reduce prices and expand output, to the extent that demand is elastic.

What is the impact of these changes on overall productivity? In a Cobb-Douglas framework, index number productivity can be calculated as:

$$\log A = \log R - \sum_i \alpha_i \log X_i,$$

or log revenue less the share-weighted difference in log inputs X_i.

Table 10 shows the change in input cost in each factor of production due to the treatment. The first two columns show the level of the input used in the control and treatment groups. The third column shows the share increase in each input due to the treatment. The last two columns give the cost share and the contribution of the change in each input to the change in total cost of production for the plant.

Though the treatment caused very large increases in high-skill labor and a large increase in capital, these inputs, especially high-skill labor, have very small shares of cost. Therefore, overall, input costs are estimated to have increased in the treatment by a 0.18 share. Most of this weighted increase in cost, in fact, is due to increases in energy expenditure, which, as previously discussed, is insignificantly different in the treatment and control groups. If we omit increases in energy expenditure from the cost share calculation we find a weighted increase in input costs of 0.12. This change is the same size as the imprecisely estimated 0.12 share increases in output and revenue discussed earlier. Therefore, we cannot reject that the audit treatment, while greatly changing the composition of inputs, did not increase overall plant productivity.

This conclusion is tentative, both for reasons of statistical power and model specification. In particular, a Cobb-Douglas specification, which imposes a constant elasticity of substitution between all pairs of inputs, is inconsistent with the observed empirical results, which imply a much greater response of high-skill labor and capital to energy-efficiency changes, than is observed for other factors. Ongoing analysis will estimate productivity changes in a theoretical framework consistent with the reduced-form empirical results.

5 Conclusion

This paper uses a large-scale randomized-controlled trial to study the adoption of energy-efficiency investments in a sample of industrial plants with high energy demand. Working under an existing state government subsidy program, sponsored by the Gujarat, India, Department of Climate Change, expert energy consultants recommend adoption of high-return measures totaling two percent of capital stock to achieve savings of ten percent of energy bills.

Treated plants improved plant efficiency, but also increased capacity utilization of newly efficient systems, generating a short-lived and insignificant decline in energy consumption. The larger effects of the treatment were on a modernization of production—treatment plants increased high-skill labor and capital, holding low-skill labor constant, thus (insignificantly) increasing output while shifting input shares.

The responses to the treatment appear entirely consistent with simple production theory on the response to energy-efficiency investment, in which energy use is partly complementary to high-skill labor and capital and firms face elastic output demand. In this case, we would expect that firms would partially offset increases in energy efficiency through a combination of a relative shift towards energy and an expansion of output. Factors of production complementary to energy, which appear to be skill and capital, would expand with increases in efficiency also, further increasing output above the direct effect on energy input. The net effect of these changes is roughly zero impact on plant productivity, albeit imprecisely measured.

One of the novel aspects of this paper is its focus on the efficiency of firms. The closest prior work is Bloom et al. (2013), who find that management consulting greatly increases productivity, and profits, for Indian textile mills. Both experiments find rather large changes in the skill mix and output: in the Bloom et al. (2013) experiemnt, from a very strong treatment that supplieds hundreds of thousands of dollars of skilled labor, in this case, from plants that endogenously respond to an energy audit by hiring skilled labor of their own. The results differ mainly in the estimated effects on profits and/or productivity. My findings suggest it is important to take into account shifts in all dimensions of inputs simultaneously to measure whether plants profited from an improvement in efficiency.

With respect to climate policy, the finding of no energy savings from energy audits joins a set of recent and ongoing research that casts doubt on the extent to which interventions may wring savings from any energy-efficiency gap (Fowlie, Greenstone and Wolfram, 2015; Davis, Fuchs and Gertler, 2014). These findings echo, in different settings and with cleaner research designs, those of earlier work questioning the returns to energy-efficiency investment in the field (Joskow and Marron, 1992; Metcalf and Hassett, 1999). This research collectively is of fresh policy importance, since the U.S. EPA's Clean Power Plan, California's AB 32 and other climate policies often *assume* that energy-efficiency programs will achieve high and additional returns (Fowlie et al., 2014). If these savings do not materialize, then allowing energy-efficiency this privileged position will raise costs and undermine the efficacy of regulation.

An old line of thinking suggests that improvements in energy efficiency, since they make energy cheaper, only increase demand for energy in the long-run (Jevons, 1905). This behavioral response appears in careful long-run micro-economic studies; e.g., Nordhaus (1996) describes huge increases in lighting efficiency over centuries and finds correspondingly massive falls in price and increases in consumption. It also appears in the present study and other work where consumers respond to efficiency by increasing consumption of energy services (Davis, Fuchs and Gertler, 2014). Economists view these changes as improving utility, for consumers, or profits, for firms, by allowing people to adapt in the face of new effective prices. In a narrow view of policies to reduce energy consumption and emissions, however, these behavioral responses give back part of the projected energy savings. Subsidizing efficiency, through information, capital subsidies, or whatever means, is therefore not a good substitute for taxing externalities. A policy framework that relies on pushing efficiency or efficiency targets, rather than setting actual limits on emissions and funding unconditional transfers, may therefore raise the costs for all the world of abating carbon emissions.

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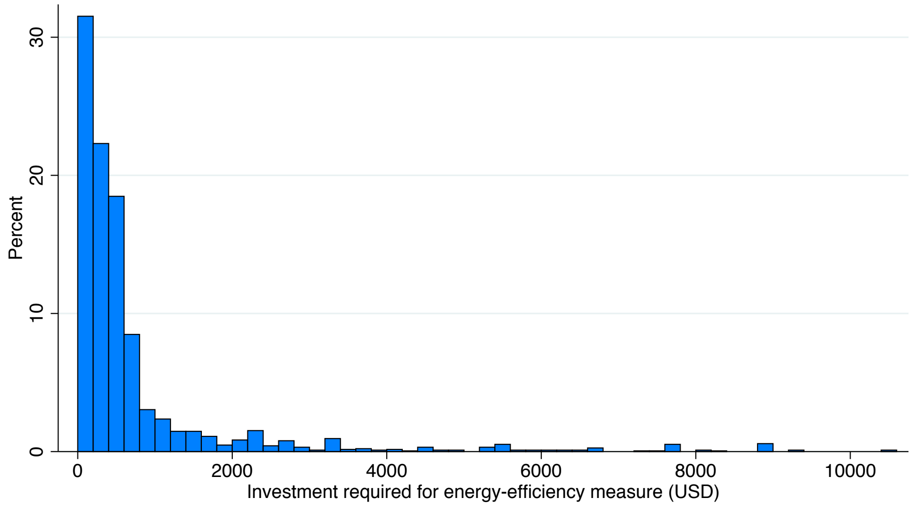
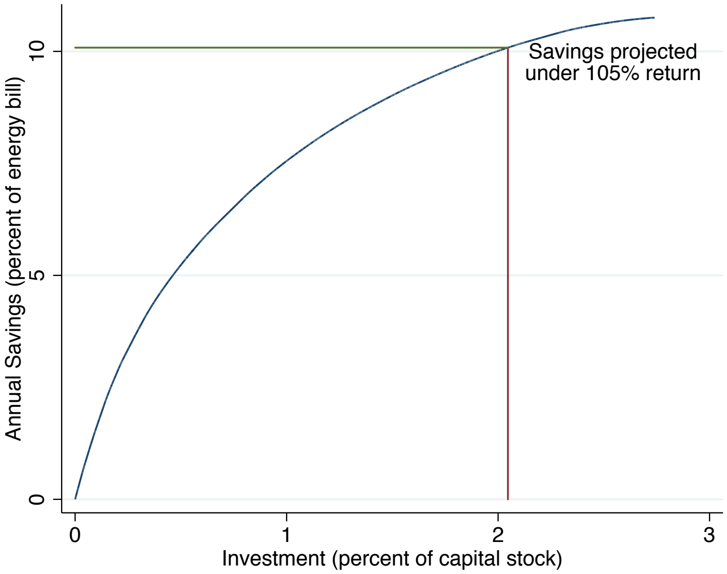
6 Figures

Figure 1: Capital Needed for Energy-Efficiency Investments



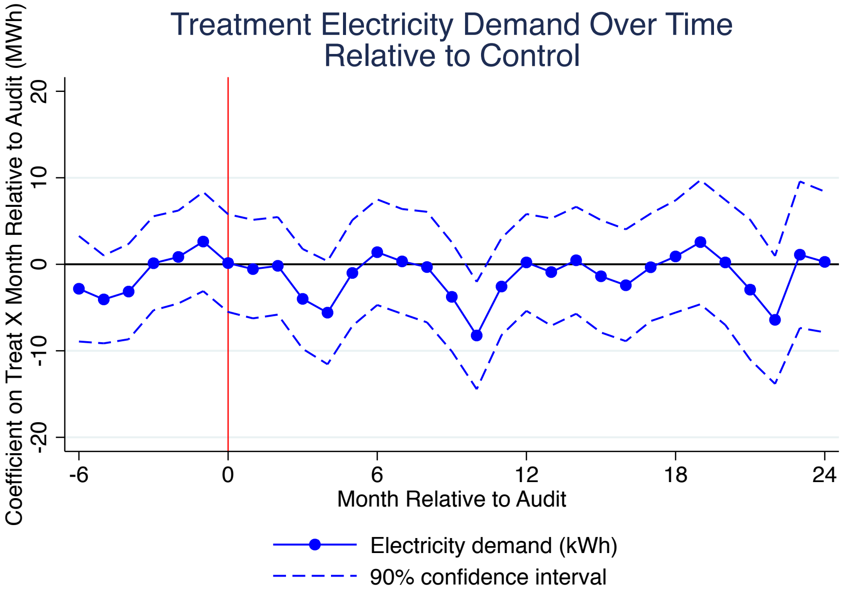
The figure shows the distribution of investment costs for measures recommended in energy audits in the energy audit treatment group of plants. Each bin is USD 200 wide and the distribution is truncated at the 97.5th percentile (USD 11,111) for clarity. The investments are for 1,959 different measures recommended to 173 treatment plants.

Figure 2: Projected Returns on Investment in Energy-EFficiency



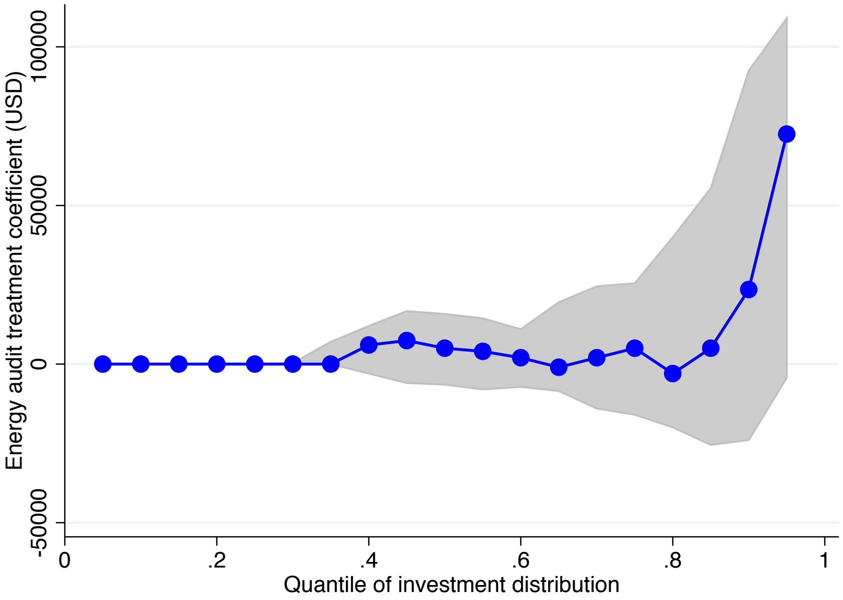
The figure summarizes the projected investments and energy savings in energy audits of treatment plants by putting measures in decreasing order of projected returns and then scaling cumulative investment and savings as a fraction of the size of the average plant. That is, $TotalInvestmentScaled = TotalInvestment/TotalPlantCapital$ and $TotalSavingsScaled = TotalSavings/TotalPlantEnergyBill$. The vertical and horizontal lines indicate the investments and savings projected if firms applied a hurdle rate of a 105% annual return to their investment decisions, where this rate of return is drawn from the estimate of marginal returns to capital for Indian firms in Banerjee and Duflo (2014).

Figure 3: Electricity Use Over Time: All Plants



The figure shows regression coeficients estimating the effect of the energy audit treatment on electricity consumption by month relative to the timing of the energy audits for treatment plants. The specification includes strata fixed effects for baseline levels of electricity consumption and year-month fixed effects (e.g., July 2013) to control for seasonality and trends common to all plants. The month relative to audit is defined as $t = 0$ in the month the energy audit is conducted.

Figure 4: Energy Audit Assignment Quantile Treatment Effects



The figure shows quantile treatment effects for the energy audit treatment with investment as the dependent variable. Coefficients $\beta_1(\tau)$ are reported for quantiles from $\tau = 0.05$ to $\tau = 0.95$ in increments of 0.05. All specifications control for energy manager treatment assignment.

7 Tables

Table 1: Experimental Design and Compliance

	Control (1)	Treatment (2)	Total (3)
A. Treatment Assignments			
	Energy Audit Treatment		
Energy Manager Treatment			
Total	216	219	435
Control	0	81	81
Treatment	0	83	83
Not assigned	216	55	271
B. Treatment Completion			
Energy Audit Treatment			
Share of plants doing energy audit	0.12	0.79	0.67***
			(0.035)
Energy Manager Treatment			
Share of plants using energy manager	0.12	0.35	0.23***
			(0.064)

The table shows the experimental design and treatment assignments, in Panel A, and the actual completion of energy audits or use of energy managers, in Panel B. In Panel A the columns indicate energy audit treatment assignment and the rows energy manager treatment assignment and each cell reports the number of plants assigned to that combination of treatments. Plants are assigned to the energy manager treatment conditional on completing the energy audit treatment and expressing interest in implementation. In Panel B the columns indicate treatment assignment status for the energy audit treatment, in the first row, and the energy manager treatment, in the second row. Each table entry gives the share of plants completing the treatment, or similar consultancy outside the experiment, conditional on the treatment assignment shown by the column.

Table 2: Balance of Baseline Covariates by Energy Audit Treatment

	Treatment (1)	Control (2)	Difference (3)
Contract demand (kVA)	200.9	191.9	8.98
	[172.1]	[171.7]	(16.5)
Electricity bill (Annual USD 000s)	85.7	82.6	3.08
	[109.9]	[106.3]	(10.4)
Fuel bill (Annual USD 000s)	110.2	114.9	-4.63
	[428.5]	[275.0]	(34.6)
Employees	83.6	82.7	0.97
	[112.7]	[117.5]	(11.2)
Capital (USD 000s)	529.0	581.6	-52.6
	[750.3]	[813.1]	(81.4)
Sales (USD 000s)	1677.2	1809.9	-132.7
	[2427.7]	[3725.4]	(320.2)
Uses lignite (=1)	0.29	0.32	-0.029
	[0.46]	[0.47]	(0.045)
Uses coal (=1)	0.23	0.19	0.036
	[0.42]	[0.39]	(0.039)
Uses diesel oil (=1)	0.11	0.16	-0.051
	[0.31]	[0.37]	(0.032)
Uses gas (=1)	0.47	0.55	-0.081*
	[0.50]	[0.50]	(0.048)
Observations	217	216	433

The table shows means of baseline characteristics for treatment and control plants and the difference between these groups, estimated as the coefficient on energy audit treatment assignment in a regression of each outcome on treatment and a set of baseline electricity use strata dummies. Standard deviations of each variable are in brackets and standard errors of each estimated difference in parentheses. Employment, capital and sales are reported at baseline for 422, 369 and 383 total plants, respectively. Statistical significance of differences is marked by * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$.

Table 3: Frequency of Energy-Saving Measures

	Measure Prevalence		Investment Size (USD)		Return (%)
	Plant Share (1)	Number if Any (2)	Mean (3)	Median (4)	Median (5)
Total	1.00	12.04	1249.06	361.11	104
Lighting	0.82	1.57	1304.40	305.56	94
Motor sizing / efficiency	0.78	10.13	1029.29	361.11	101
Insulation	0.46	2.17	476.50	260.00	175
Electricity Tariff	0.42	1.40	579.40	253.33	154
Heat Recovery	0.39	1.27	5956.81	5581.51	220
Maintenance / Other	0.23	1.38	1083.40	536.11	1601
Automation	0.10	1.06	2017.35	666.67	155
Compressors	0.09	1.20	3495.29	1111.11	80
Drives / belts / pulleys	0.07	1.91	2666.51	2000.00	71

The table shows characteristics of investments recommended in energy audits of treatment plants. The rows give the type of equipment or system that the measure involves, and the columns give statistics on the prevalence (columns 1 and 2), investment cost (columns 3 and 4) and returns (column 5) on these measures. A total of 1,959 measures have non-zero investment and so finite returns.

Table 4: Equipment-Level Investment on Treatment

	Total Investment (USD)		Upgrades (USD)		Maintenance (USD)	
	(1)	(2)	(3)	(4)	(5)	(6)
Energy audit treatment (=1)	291.8	367.7	106.9	264.9	184.9	102.8
	(282.1)	(256.3)	(193.9)	(220.4)	(183.9)	(129.8)
Energy manager treatment (=1)		-189.6		-394.5		204.9
		(560.6)		(358.2)		(384.5)
Control mean	762.2	762.2	323.8	323.8	438.4	438.4
p-value for H_0 : Energy audit treatment = 0	0.30	0.15	0.58	0.23	0.32	0.43
p-value for H_1 : Energy audit treatment = 6981	0.00	0.00				
Observations	329	329	329	329	329	329

The table shows coefficients from regressions of investment in energy-efficient equipment at the plant level on treatment status for sample plants. Investment in energy-using equipment maintenance and upgrades is asked of plant managers or staff in the Endline Survey with reference to specific pieces of equipment for a period of January, 2011 through the time of the endline survey, a mean time of 2.25 years. The columns of the table show different categories of investment, in upgrades (changing a piece of equipment) or maintenance (maintaining or improving an already-existing piece of equipment). The rows show coefficients on the assignment to the two experimental treatments from the specification, with standard errors in parentheses beneath and statistical significance indicated by * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$. Regressions include fixed effects for baseline electricity consumption strata.

Table 5: Heterogeneity in Equipment-Level Efficiency Investment

	Equipment-level Investment (USD)			
	(1)	(2)	(3)	(4)
Audit treatment assignment (=1)	431.6*	187.9	60.55	674.4*
	(233.2)	(300.6)	(323.3)	(387.6)
Energy bill, annual (USD ’000s)	1.143*			
	(0.627)			
Energy bill, annual (USD ’000s) × Audit treatment	-1.067			
	(0.661)			
Electricity demand (kVA)		2.287***		
		(0.859)		
Electricity demand (kVA) × Audit treatment		-0.308		
		(1.179)		
Employees, number			1.936**	
			(0.983)	
Employees, number × Audit treatment			0.802	
			(2.157)	
Projected payback period (months) × Audit treatment				-20.39*
				(12.23)
Implementation treatment	Yes	Yes	Yes	Yes
Control mean	762.2	762.2	762.2	762.2
Observations	235.7	208.2	100.4	20.0
N	310	328	300	290

The table shows regressions of the sum of equipment-level investment in energy efficiency on plant characteristics and interactions of characteristics with treatment status. The plant characteristics in columns 1 through 3 are measured in the baseline survey for treatment and control plants: annual energy bills, electricity contract demand (the electricity load a plant is signed up for with the utility) and number of employees. The fourth column interacts treatment status with the mean payback period, in months, for investments recommended in energy audits under the treatment. Payback period is the ratio of the projected capital investment for a measure over the monthly energy savings and is commonly used as a way to present returns in energy audits. Because projected payback periods are only observed in audited treatment plants, the specification in column 4 include no payback period main effect. All regressions include a constant and show robust standard errors in parentheses. Statistical significane is denoted by * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Physical Efficiency of Plant Equipment on Treatment Status

	Efficiency (1)	Hours used per day (2)
Panel A. All Systems		
Energy audit treatment (=1)	0.0848	1.115**
	(0.0650)	(0.493)
Control mean	0.0	16.7
Observations	2175	2134
Panel B. Boiler		
Energy audit treatment (=1)	0.287*	1.922*
	(0.166)	(1.142)
Control mean	-0.1	16.3
Observations	292	283
Panel C. Motors		
Energy audit treatment (=1)	-0.0762	0.801
	(0.0786)	(0.570)
Control mean	0.0	17.0
Observations	1570	1544
Panel D. Jet-Dyeing Machines (Textile Plants Only)		
Energy audit treatment (=1)	0.142	1.100
	(0.250)	(1.157)
Control mean	-0.0	19.4
Observations	128	128
Panel E. Reaction Vessels (Chemical Plants Only)		
Energy audit treatment (=1)	0.152	0.965
	(0.360)	(2.256)
Control mean	-0.0	13.5
Observations	185	179

The table shows regressions of the physical efficiency and hours of use of pieces of equipment within plants on energy audit treatement status. Physical efficiency is measured with a standardized index of efficiency composed of the average of standardized physical efficiency measures, such as the presence of insulation or the external temperature of an insulated vessel, where each standardized measure is signed so that efficiency is monotonically increasing in the index. These measures are recorded at the level of the piece of equipment and so multiple measures may be available per plant. Hours of operation are obtained by asking plant managers or staff how often different equipment is run. Regressions include baseline electricity demand strata and controls for energy manager treatment assignment. Standard errors, clustered at the plant level, are in parentheses, with statistical significance marked by * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$.

Table 7: Electricity Demand on Treatment

	(1) Demand (kWh)	(2) Bill (USD)
Energy audit treatment (=1) ×	-1951.5	-67.70
First year post audit	(2409.2)	(253.2)
Energy audit treatment (=1) ×	2348.9	98.96
Second year post audit	(3870.6)	(418.0)
Control mean	56715.8	7164.8
Plants	322	322
Observations Per Plant	24.3	24.3
Observations	7811	7809

The table shows coefficients from regressions of monthly electricity demand and energy charges on interactions between energy audit treatment assignment and the time since energy audit in months. The regressions include controls for baseline electricity demand strata and year-month fixed effects (e.g., July 2013). Standard errors clustered at the plant level in parentheses with statistical significance indicated by * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$.

Table 8: Plant Sales and Inputs by Treatment Status

	Treatment	Control	Difference
Sales (USD '000s)	2288.1	2036.4	251.7
	[3456.2]	[2176.3]	(399.8)
	108	103	211
High-skill labor (USD '000s)	48.5	28.0	20.5***
	[81.9]	[54.3]	(7.62)
	160	169	329
Low-skill labor (USD '000s)	153.8	151.3	2.52
	[222.1]	[253.8]	(26.4)
	160	169	329
Capital (USD '000s)	158.3	106.0	52.3*
	[283.7]	[125.0]	(27.9)
	115	125	240
Materials (USD '000s)	631.6	586.6	45.0
	[787.0]	[764.7]	(99.7)
	113	130	243
Energy (USD '000s)	440.2	368.3	71.9
	[409.7]	[321.0]	(58.1)
	69	89	158

The table reports factors of production from the endline survey. Sales, high-skill labor, low-skill labor, capital and materials are responses to questions, asked of the plant owner or manager, on the total value of those inputs used in the last complete fiscal year (2011-12). The capital value shown in the table is the estimated capital input rent, based on multiplying the survey answer for the plant's total market value of capital by an assumed capital rental rate of 0.15. The energy input is calculated based on the sum of fuel bills, from survey responses, and electricity consumption, from administrative data on utility bills, aggregated over the same period. Inputs and output are sensitive information to plants and were selectively reported; hence, the varying sample sizes for each input. Energy input is shown in the table only for plants that reported both their electricity and fuel expenses. The first two columns in the table show the means of each factor for the treatment and control groups, respectively, and the last column the difference in means across groups. In the third column standard errors are shown in parentheses and statistical significance is denoted by * p lt 0.10, ** p lt 0.05, *** p lt 0.01.

Table 9: Employment at Endline by Treatment Status

	Treatment	Control	Difference
All employees			
Number	100.9	91.1	9.74
	[129.7]	[141.2]	(14.9)
Pay (USD ’000s)	184.0	156.2	27.7
	[278.2]	[281.2]	(30.7)
Managers			
Number	3.24	2.35	0.89*
	[4.68]	[4.15]	(0.51)
Pay (USD ’000s)	21.4	12.9	8.50**
	[36.0]	[29.0]	(4.01)
Technical staff			
Number	9.06	6.04	3.02**
	[13.2]	[10.6]	(1.35)
Pay (USD ’000s)	36.5	21.5	15.0**
	[63.1]	[37.5]	(6.23)
Workers			
Number	94.8	88.6	6.24
	[120.5]	[138.4]	(14.7)
Pay (USD ’000s)	154.0	152.5	1.50
	[232.5]	[272.5]	(30.0)

The table shows the composition of employment by treatment status in the endline survey. The survey asked the plant owner or manager about the total number of people employed in different categories as well as their total annual pay. Managers are “Management (at plant)” employees; technical staff are “Technical or supervisory (at shop floor, excluding management)” and workers are “Workers (laborers at shop floor).” The first two columns show the means and standard deviations of these variables by treatment status and the third shows the difference (treatment less control) and the standard error of this difference, with statistical significance denoted by * $p < 0.10$, ** $p < 0.05$ and *** $p < 0.01$.

Table 10: Summary of Change in Input Costs

Input	Cost (USD ’000s)		% Increase, Factor	Cost share	% Increase, Total
	Control	Treatment			
Capital	106	158	0.49	0.10	0.05
Materials	587	632	0.08	0.56	0.04
High-skill	28	49	0.75	0.03	0.02
Low-skill	151	154	0.02	0.14	0.00
Energy	368	440	0.20	0.35	0.07
Total	1240				0.18

The table shows the change in input cost in each factor of production due to the treatment. The first two columns show the level of the input used in the control and treatment groups. The third column shows the share increase in each input due to the treatment. The last two columns give the cost share and the contribution of the change in each input to the change in total cost of production for the plant.

A Appendix

Table A1: Plant Interest in Energy Audit

	Plant interest	
	Number (1)	Percent (2)
Interested	490	53.0
Already have consultant	38	4.11
Energy not a large cost	40	4.32
Scope of savings not large	50	5.41
Other	307	33.2
Total	925	100

The table shows interest in joining the experimental sample, as solicited by energy consultants, amongst plants in the larger population of membership rolls in local industrial associations.

Table A2: Selection into the Sample

	Sample mean [sd]		
	Interested	Not	Difference
Electricity load in kW	65.9	60.4	5.53
	[67.4]	[78.0]	(11.3)
Capital (USD ’000s)	231.7	130.6	101.0
	[445.0]	[165.5]	(63.2)
Capital, plant (USD ’000s)	96.5	77.0	19.5
	[184.8]	[111.1]	(27.2)
Capital, equipment (USD ’000s)	7.72	7.39	0.33
	[41.0]	[36.5]	(6.41)
Capital, building (USD ’000s)	76.8	29.1	47.6
	[219.3]	[40.6]	(30.6)
Capital, land (USD ’000s)	50.6	17.2	33.5
	[246.4]	[14.8]	(34.3)
Employment	15.2	13.2	1.91
	[13.9]	[11.4]	(2.14)
Observations	154	52	

The table compares observable characteristics of plants interested or not interested in participating the experiment in data from industrial registrations with the state of Gujarat. Industrial registration data is available for a subset of 206 of the 925 plant population fo the experiment due to partial registration and limited matching. Registration data gives characteristics as reported to the government on establishment of the plant.

Table A3: Attrition in the Endline Survey

	N	%
Surveyed	334	76.8
Not surveyed	101	23.2
Shut down/Sold off	42	9.7
Refused	52	12.0
Other	7	1.6
Total	435	100.0

Shut down/sold off includes plants that were permanently closed and plants that were temporarily closed during repeated survey visits. *Refused* includes plants that were operating at the time of the visit, but that refused to respond. *Other* includes plants that moved or that could not be contacted.

Table A4: Endline Attrition by Treatment Status

	Treatment	Control	Difference
Surveyed	0.744	0.792	-0.048
	[0.437]	[0.407]	(0.040)
Shut down/Sold off	0.096	0.097	-0.001
	[0.295]	[0.297]	(0.028)
Refused	0.142	0.097	0.045
	[0.349]	[0.297]	(0.031)
Other	0.018	0.014	0.004
	[0.134]	[0.117]	(0.012)
Observations	219	216	

Shut down/sold off includes plants that were permanently closed and plants that were temporarily closed during repeated survey visits. *Refused* includes plants that were operating at the time of the visit, but that refused to respond. *Other* includes plants that moved or that could not be contacted.