CLEAN *by* Design

NRDC's Ten Best Practices for Textile Mills to Save Money and Reduce Pollution

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A PRACTICAL GUIDE FOR RESPONSIBLE SOURCING

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Executive Summary

From the clothes on our backs to the curtains in our homes, thousands of everyday items we rely on are produced by the world's textile industry. Dyeing and finishing one ton of fabric can result in the pollution of up to 200 tons of water with a suite of harmful chemicals and consume tremendous amounts of energy for steam and hot water. With the industry now centered in countries with still developing environmental regulatory systems, such as China, India, Bangladesh, and Vietnam, textile manufacturing has a huge environmental footprint.

To address the rapidly increasing global effect of this industry, NRDC and a group of apparel retailer and brand partners are spearheading the Responsible Sourcing Initiative (RSI) to curb pollution in the sector while saving the industry money. Starting in China, the world's largest center of manufacturing, NRDC reviewed more than a dozen textile mills and studied five in-depth to identify simple, cost-saving opportunities to reduce water, energy, and chemical use—via improvements in manufacturing efficiency.

This initiative does not call for large-scale retooling of the textile industry. To the contrary, the opportunities summarized here are all easy-to-implement and low-cost opportunities that pay for themselves in eight months or less. Even absent concern about environmental impacts or government oversight, these opportunities should be pursued because they enhance the productivity of mills and are good for business.

The Responsible Sourcing Initiative is part of the larger "Clean by Design" effort NRDC has undertaken to address the environmental impacts of the fashion and apparel industries. Clean by Design addresses all major impacts—from fiber growth to dye selection, fabric sourcing to consumer care.

This Best Practice Guide recommends metering to measure resource use as a point of entry for improvement. It then summarizes ten best practices that save water, energy, fuel, and electricity with little upfront investment and no risk to product delivery times, price, or quality (see Table 1). For mills ready for more, there are additional recommendations for process optimization improvements. Finally, this guide presents a list of very simple good housekeeping methods that will increase savings and efficiency at all mills with very little effort, even for those mills not yet ready to undertake other recommended improvements.

Table 1: Clean by Design's Ten Best Practices

Practice	Percentage Resources Saved	Cost	Payback Period
Leak detection, preventive maintenance, improved cleaning	Water: 2-5%; Energy: 1.5-5%	Insignificant	< 1 month
Reuse cooling water : from singeing from air compressor system from preshrink	Energy: 1.6-1.8% Water: 2-5% Water: 2% Water: 1%	$1,500	< 1 month
Reuse condensate	Water: 2-3%; Energy: 0.8-3.2%	variable	1 month - 1 year
Reuse process water: from bleaching from mercerizing	 Water: 4% Water: 3%	$3,000 - $30,000	< 1 month
Recover heat from hot rinse water	Energy: 2-12%	$44,000 - $95,000	2 - 4 months
Prescreen coal	Energy: 3%	$35,000	5 months
Maintain steam traps	Energy: 1-5%	Insignificant	< 1 month
Insulate pipes, valves and flanges	Energy: 0.01-0.5%	$4,500	< 1 month
Recover heat from smokestacks	Energy: 1%	$22,000	8 months
Optimize compressed air system	Electricity: 0.3-3%	Insignificant	< 1 month

Overview

China has more than 50,000 textile mills, producing fabric used in products found in closets, cupboards, and kitchens across America and the world. According to surveys measuring natural resource use in all industries, textile dyeing and finishing mills use considerably more water than most—as much as 200 tons of water for every ton of textiles produced. Steam used in the manufacturing process is often generated in inefficient and polluting coal-fired industrial boilers. And then there are the chemicals used in textile processing, which include toxic and oxygen-depleting constituents that have harmful impacts on human health and the environment when not properly treated. When combined with tremendous production inefficiencies, many textile mills in China and elsewhere in the developing world fall far below global standards for using resources—whether they be water, coal, electricity, time, or money—efficiently and effectively.

Whereas North America and Europe have few textile mills and mature environmental regulatory structures, China and most other developing nations lack the capacity either to adequately monitor the thousands of mills operating within their borders or to enforce existing standards. In response to this problem, NRDC partnered with six pioneering multinational apparel retailers and brands to launch the Responsible Sourcing Initiative (RSI), as part of the larger Clean by Design effort to address the environmental impacts of the fashion industry. RSI's purpose was to close the gap between the quality and scale of industrial manufacturing in the developing world and the governments' capacities to address the environmental impacts that result. The best way to achieve this goal was to reduce waste by targeting resource inefficiencies in the manufacturing process, thereby enhancing the profitability of mills while reducing their environmental footprint.

Through expert efficiency assessments of real-world manufacturing practices in five typical Chinese mills, NRDC identified best practices that would immediately make the dyeing and finishing process more efficient and deliver substantial environmental improvement at the same time—thereby constructing a practical win-win framework to benefit both the environment and the bottom line (see Table 1: Ten Best Practices). Taken together, the Ten Best Practices can save approximately 25 percent of the water and 30 percent of the energy used in a typical cotton fabric dyeing mill—all with initiatives that pay themselves back in less than eight months.

Of course, compliance with local environmental emission and discharge standards remains crucial for all textile manufacturing, and multinational apparel buyers must continue to insist on compliance as a prerequisite for doing business; even the best-run and most efficient manufacturing practices will still generate pollution that must be treated prior to discharge. The Best Practice Guide provides an important supplement to reducing the environmental footprint of textile manufacturing with its cost- and resource-saving improvements, but it will not substitute for or eliminate the need for treatment altogether.

A short description of the five textile mills studied in depth is provided in Appendix A. The mills all processed cotton fabric but ranged in size and type of production. Some dyed woven fabric, some dyed knitted fabric, and some dyed yarn. All five of the mills fell in the "middle" range of production efficiency—they were neither state-of-the-art manufacturing operations nor the worst performers. Therefore, the opportunities identified in these mills should be very widely applicable to thousands of mills across China and elsewhere in the developing world.

First Things First:
Install Meters to Measure Savings

One best practice underpins all of the other opportunities recommended by NRDC and should be adopted immediately by all dyeing and finishing textile mills**: measuring consumption with meters that track water, steam, and electricity consumption in total and at the process and equipment levels.**

RSI assessments revealed that although many textile mills in China track *total* water, coal, and electricity consumption, they do not know specifically how resources are used in specific areas inside the factory or in particularly energy-intensive equipment. Meters, or better yet, measurement software, at key locations inside a mill enable a factory to closely track resource and energy consumption for specific processes, directing managers to focus their resources on improving efficiency in those processes that are the most resource intensive. With one exception, the mills investigated in RSI had meters that tracked total mill consumption parameters, but had little or nothing at the workshop or equipment level.

Installing and operating accurate meters and/or measuring software are fundamental steps to benchmarking performance and to initiating efficiency improvements. It allows plants to identify and respond to leaks and to detect unusual spikes in resource use, and it provides positive feedback on the effectiveness of measures that mills take to improve their processes. In this way, meters and measurement software reinforce the benefits of efficiency measures and encourage continuous improvement. Importantly, measurement software allows process efficiency information to be sent to other locations electronically, thus enabling benchmarking of performance and identification of best-in-practice mills in an objective and straightforward manner.

Since 2006, the Chinese government has required the three tiers of metering that RSI is recommending:[1,2]

- **Level 1:** Total energy used in the factory (Energy consumption unit):
  All factories required to install
- **Level 2:** At the individual workshop level (Energy consumption sub-unit):
  Percentage of meters installed: Water meters 95 percent, steam meters 80 percent, electricity meters 100 percent
- **Level 3:** Main energy-consumptive equipment:
  Percentage of meters installed: Water meters 80 percent, steam meters 70 percent, electricity meters 95 percent

Given the government requirement, this recommendation is not only a key cornerstone of RSI's recommended best practices, but it is also an essential element of compliance status for a Chinese mill.

Meters and measurement software are inexpensive. Water and electricity meters cost US$1,000 or less each. Steam meters are more expensive at an estimated US$3,000 each.[3] Measurement software is available for US$15,000, a figure that includes the price of remote collection.[4]

Ten Best Practices
for Saving Water, Energy, and Money

Although some improvements in textile manufacturing require relatively large investments in updated equipment, Clean by Design's Responsible Sourcing Initiative (RSI) sought opportunities that were practical, low-cost (or even no-cost) improvement measures. RSI particularly focused on factory infrastructure improvements that would improve the production of steam and water heating, recycle process water, and recover heat. These infrastructure initiatives provide a particularly easy starting point for increasing manufacturing efficiency when compared to process optimization methods. For each opportunity identified, RSI evaluated:

- **Costs**—both upfront investment and ongoing operational costs;
- **Payback period**—the time required to recoup upfront investment through savings in water, materials, and energy costs; and
- **Resource savings** (water, energy, chemicals).

All cost, return, and impact estimations and calculations were made from the five factories audited in this initiative. The RSI team then selected practices based on greatest impact, lowest cost, and quickest return. (See Appendix B for full list of 33 practices evaluated and selection criteria.)

Seven of the ten best practices cost less than US$5,000 each; three of these cost almost nothing (see Table 1).[5] None requires more than eight months to recoup costs. From an environmental standpoint, the best practices each deliver savings of at least 1.5 tons of water, 10 kg of coal, or 10 kWh of electricity per ton of fabric. In total, if implemented together at the same mill, these 10 improvements could reduce consumption of electricity by as much 3 percent, water by as much 24 percent, and energy (fuel) by as much as 31 percent.

Four Water Saving Best Practices

Water consumption varies among processes within a textile mill as well as by machine type and setup. Wet processing (i.e. pretreating, dyeing, and finishing) typically accounts for the majority of water consumption and wastewater discharge. Recycling and reuse measures that focus on these processes yield great savings, and, since the water recovered is often hot, these improvements save energy as well. Steam condensate and non-contact cooling water (such as water used to cool a singeing machine) is a second valuable source of water to recover because it is high in both quality and temperature. Finally, water is used for general washing and cleaning throughout the factory, and good housekeeping practices can substantially reduce wasteful use of water in cleaning as well.

RSI identified four best practices to conserve water (see Table 2). A mill that implemented all of the water best practices suggested would save between 27 and 37 tons of water per ton of production—13 to 24 percent of its total water use.[6]

Table 2: Water Best Practices

Practice		Water Savings (ton/ton fabric)	Percentage Savings
Leak detection, preventive maintenance, improved housekeeping		4 – 7.6	2-5
Reuse of cooling water	From singeing	3.2 – 7.4	2-5
	From air compressor	3.89	2
	From preshrink	1.44	1
Reuse of condensate		3.8 – 6.0	2-3
Reuse of process water	From bleaching	6.47	4
	From mercerizing[7]	4.54	3

Leak detection, preventive maintenance, improved cleaning

Although individual leaks may not seem important in the overall consumption picture, they can be responsible for a surprisingly significant loss of resources over the course of a year. For example, one 2 mm steam leak with saturated steam of 5 kg/cm^2 consumes an estimated 10.34 tons of standard coal per year.[8] Similarly, the power loss from one compressed air leak of about 4 mm with 0.6 mPa pressure is 6.5 kilowatts in electricity, an annual loss of about 52000 KwH.[9,10] Based on observations made during the mill assessments, RSI estimated conservatively that leaks of water and steam were responsible for between 1 percent and 5 percent of losses of water and energy.[11] In fact, these values could be higher judging from the relevant literature.[12] Additional savings can be expected from improved oversight of the water used in cleaning operations; for example, by installing shut-off valves and turning off hoses when they are not in use.

This best practice consists of routinely investigating sources of leaks in water, steam, and compressed air and implementing an effective preventive maintenance program, requiring virtually no investment costs and thus delivering instant payback.

Reuse of non-contact cooling water from singeing, air compressor, and preshrink systems

Non-contact cooling water should always be recycled. It is high in quality and temperature and can thus be reused beneficially in various processes, such as in desizing, scouring, washing, or rinsing. Furthermore, at a discharge temperature of 45 °C and considerable water volume, discharge of cooling water stresses the wastewater treatment system. It is thus highly beneficial to keep such large quantities of hot, clean water out of the treatment system. RSI found that some mills were either not reusing this water at all or were using it in cold water processes that did not benefit from the heat.

RSI identified three sources of non-contact cooling water that can be most beneficially recaptured and reused: water used in singeing, preshrink machines, and in air compressor systems. Other sources of cooling water may be available elsewhere in the mill as well, such as from batch jet dyeing machines.[13]

This best practice requires installation of a water reuse system—pipes, valves, pumps, holding tanks, and a control system. Investment costs are low (estimated at less than US $1,500) and return on investment is immediate (less than one month).

Cold pad batch processing

Cold pad batch processing (for both pretreatment and dyeing) is a superb method of reducing resource use in textile mills, and it saves money. In this method, alkali/hydrogen peroxide (in the case of pretreatment) or dyes are embedded into the fabric using a padder, and the fabric is then stored to allow complete reaction between the fabric and chemicals prior to rinse. Experts report that as much as 50 percent of the water and electricity and 38 percent of the steam used in pretreatment can be reduced with this method, with overall reduced costs of about 50 percent.[14] Results for dyeing are similarly impressive, particularly for energy savings, in large part because cold pad batch dyeing does not require drying and steam. Both dye penetration and fixation rates are high (15 to 25 percent improvement), which also reduces dye consumption and wastewater color problems. One mill familiar to RSI assessors converted to cold pad batch dyeing and saved approximately 3,550 tons of steam (equivalent to 461.5 tons of coal) annually with an investment of 256,000 yuan (US$37,500) and a payback time of only four months.[15] However, cold pad batch technology is limited to woven cotton fabric and works best with heavy-weight fabric and dark colors. Because of these limits in applicability, cold pad batch processing is not included in the list of ten best practices.

Reuse of steam condensate

Textile mills rely on a large amount of saturated steam in the dyeing process. Some of that steam converts into condensed water (condensate) over the course of its use. This condensate is very high in temperature and purity. One of the best places to collect large volumes of condensate in woven fabric mills is in the drying cylinders, where fabric is dried by heat from steam. Knitted mills find large sources of condensate primarily in steam traps.

The most efficient use of condensate is to return it to the boiler and convert it back into new steam. However, for companies that buy their steam from an outside supplier or whose boiler is located too far from the process, the condensate can serve as water supply for washing or desizing, thereby recovering both water and heat.

In three mills investigated by RSI, condensate went directly to wastewater without reuse. In one of these mills, the drying cylinders produced condensed water at a speed of 15 kg/h, which translated into 18,975 tons of condensed water per year, 2.5 percent of the total water consumption in the factory.[16] Energy savings accruing from this option are also quite substantial.

This best practice requires installation of pipes and lines to capture and return condensate. Estimates of investment costs have a large range and were difficult to pinpoint in RSI mills because they depend on the particular layout of the mill and the proximity of condensate sources to the boiler. Payback periods are good in all cases, between immediate (less than one month) and less than 8 months.

Reuse of process water from bleaching and mercerizing

The water discharged from bleaching and mercerizing machines can be collected and reused for other processes, instead of discharging it directly to wastewater treatment. The quality of water must be evaluated, but can often meet the quality requirements for scouring after simple pretreatment (cleanup of fibers).

This best practice requires purchasing pipes, water tanks, and electrical pumps to store and return water to the process. Estimates of investment cost range from US$3,000 to US$30,000 depending on mill size and layout, but in all cases the investment pays itself back immediately (less than one month). Some mills will not need to purchase new equipment but can adapt existing equipment and systems to this use.[17]

FIVE ENERGY (FUEL) BEST PRACTICES

The generation of steam is by far the largest energy-consuming activity in a textile mill. Usually done in an on-site industrial boiler, steam generation contributes global warming gases (mainly from carbon dioxide emissions) to the atmosphere, as well as other harmful pollutants, such as particulate matter and sulfur dioxide. With this in mind, RSI best practices for energy improvements focus on two areas: (1) improvement in operation and efficiency of the boiler itself and (2) increasing the efficiency of the use of steam in the production process through insulation and maintenance of the steam delivery system.

The cost of energy is a particularly important incentive for mills to become more energy efficient. In China, the cost of energy for textile dyeing and finishing has increased over the past decade from 8 percent of the total cost of production at the end of the twentieth century to 30 to 40 percent today.[18] Further, these energy saving measures support China's recent commitment to reduce its energy intensity, a measure of energy use per unit of production.

RSI identified five best practices to conserve energy (see Table 3). Substantial additional energy is saved with three of the best practices (described above) for water efficiency as well. A mill that implemented all of the recommended energy best practices identified would save between 448 and 1,151 kg of coal per ton of production—representing between 11 and 31 percent of its total fuel use.[19]

Table 3: Energy Best Practices

Practice	Energy Savings (kg coal/ton fabric)	Percentage Savings
Recover heat from hot rinse water	61.1-320	2-12
Prescreen coal**	79.5	3
Maintain steam traps	72-128	1-5
Recover heat from smokestack	65	1
Insulate pipes, valves, and flanges	0.2-38	0.01-0.5
Energy savings from leak detection, preventive maintenance, improved cleaning	47-340	1.5-5
Energy savings from the reuse of cooling waters	67-92	1.6-1.8
Energy savings from the reuse condensate	55-86	0.8-3.2

** Note that while these energy saving best practices were calculated based on the use of coal as a fuel, these measures (except for pre-screening coal) would also save energy at mills using natural gas, wood, or other fuels to generate heat and steam.[20]

Recover heat from hot rinse water

During manufacturing, large quantities of very hot (80 °C) water are used to rinse fabric. The heat from this rinse water can be beneficially captured and used for preheating the incoming water for the next hot rinse. This option provides an important second benefit of reducing the temperature of the wastewater prior to treatment. And yet, none of the mills assessed in RSI were recovering heat from their hot rinse water.

This best practice requires the purchase of a plate heat exchanger that can transfer the heat energy in wastewater to the incoming cold freshwater. Simple heat exchangers suffice for continuous processes. In discontinuous processes, the heat exchanger would have to be fitted with buffer tanks and process control devices.[21] This is a relatively expensive RSI opportunity, costing between US$44,000 and US$95,000 depending on mill size and layout. But in all instances the investment pays back quickly—between two and four months.

Prescreen coal

In one mill RSI investigated, raw coal was fed into the boiler and burned on stoke chains, which allowed small-sized, poor quality coal to be fed to the boiler. To address this loss, companies should adopt spiral coal screen technology to screen the raw coal. This device greatly increases the rate of separation of good and bad quality coal, increasing the calorific value of the fired coal. Such equipment produces little noise, and it is easy to operate.

This best practice requires the installation of a spiral coal screener, at an estimated cost of US$35,000. The screener would pay back its cost in five months.

Maintain steam traps

Steam traps play an important role in maintaining efficient transportation of steam through a textile mill. The traps remove moisture (i.e. condensate) from the steam lines and prevent further condensation, thereby reducing heat loss and fuel consumption. Failed steam traps allow live steam to escape into the condensate system or even to ditches. In steam systems that have not been adequately maintained, between 15 and 30 percent of the traps may have failed.[22] Half the mills that RSI investigated had a very large number of steam traps that were not functioning.

Steam traps should be replaced as soon as they go out of order. A good rule of thumb is that leaking traps should account for less than 5 percent of the trap population.[23] In addition, steam traps should be installed at appropriate intervals—typically one about every 27 yards (25 meters)—in the main steam headers.[24]

This best practice requires routine inspection of steam traps (monthly testing is recommended) and repairing or replacing broken steam traps as soon as the problem is detected. Because no significant expenses are associated with implementing this practice, it pays for itself immediately (less than one month).

Insulate pipes, valves, and flanges

Textile mills use steam in a variety of machines and processes. Because of widespread use of steam at locations across the factory, losses during steam transportation are considerable. According to industry data, the energy loss of one meter of uninsulated steam pipe could account for the equivalent of nearly three tons of wasted coal annually.[25] If all the steam pipelines in a typical factory were well insulated, heat loss through them could be reduced by up to 90 percent.[26]

All the mills assessed in RSI had great potential for energy saving through steam pipeline insulation; many had poorly insulated pipes, and valves and flanges were almost always completed ignored.

This best practice requires routine inspection and insulation of all pipes, valves, and flanges in the mill. Breaches in insulation (tears, etc.) should also be repaired and replaced. A popular insulation material is slag wool, which has good quality and high efficiency and is low in cost, although different locations may require different insulation materials.[27] This option costs only US$4,500 or less upfront and pays for itself immediately (less than one month).

Recover heat from smokestacks

Hot flue gas leaving the stack is the largest source of energy loss in a boiler, and a considerable quantity of fuel can be saved by recovering some of this energy. Gas-fired boilers are inherently better candidates for heat recovery than coal-fired boilers, because gas causes minimal corrosion problems. Corrosion-resistant materials can be used in the heat-recovery systems of boilers using other fuels, however, to minimize the impact of corrosion.

RSI found that boiler fumes are often directly discharged into the atmosphere without any capture of their heat energy. Instead, where appropriate, this heat can be used to preheat boiler feed water or to create steam for the steam network.

This best practice requires the installation of a waste heat boiler that uses smokestack heat to make steam that may then be added into the steam network. This option costs an estimated US$22,000 up front and pays itself back in eight months.

ONE ELECTRICITY BEST PRACTICE

Electricity is estimated to account for no more than 20 percent of total energy consumption at a typical dyeing and finishing textile mill.[28] Thus, even large savings of electricity will tend to make only a minor contribution to the overall energy consumption at a mill. Nevertheless, one practice, optimizing the compressed air system, results in sufficient electricity savings to qualify as an RSI best practice.

A mill that implemented this electricity best practice would save between 2 and 59 kWh per ton of production—between 0.3 percent and 3 percent of its total electricity use (see Table 4).

Table 4: Electricity Best Practice

Practice	Electricity Savings (kWh/ton fabric)	Percentage Savings
Optimize compressed air system	2.3-59.1	0.3-3.0

Optimize compressed air system

Instrumentation consumes large amounts of compressed air at many individual locations in a textile mill, but is susceptible to leakage. Most such leaks are at threaded connection points, rubber hose connections, valves, regulators, seals, and in old pneumatic equipment. In all, compressed air leaks can account for 20 percent to 75 percent of air demand in a plant that has no regular maintenance policy.[29] Air leaks from knitting operations are very common and can be quite large; these exact a large invisible cost, and the reduced pressure may impair the operation of the dyeing and finishing machines. Integrated mills that contain knitting operations should check the compressed air systems in that area as well as in the dyeing and finishing area itself.[30]

Working pressure is commonly set according to the maximum pressure needed by the users of the system to compensate for pressure drop between the compressor and the target equipment. However, it is often possible to reduce this pressure without negative effects on manufacturing. Optimizing pressure settings saves energy and reduces the volume of air loss through leaks.[31] In addition, optimization of the size of the air pipelines can also be very useful; as a general rule, larger diameter air lines suffer less from pressure drop problems and will enable mills to successfully lower their air pressures.

This best practice requires fixing leaks in the air system and checking and optimizing pressure settings on a regular basis, at least annually. The option costs virtually nothing and pays for itself immediately.

Process Improvement
Recommendations for Mills Ready to do More

The RSI best practices described above deliver results through specific engineering improvements to factory infrastructure (boilers, steam, electricity, etc.) that provide the steam and hot water, electricity, and compressed air in the mill and also through such green initiatives as recycling and reusing water and heat wherever possible.[32] The other area where improvement is possible is **process optimization: modifying the pretreatment, dyeing, and finishing processes themselves so that they use less water, energy, and chemicals.**

Processes can be modified to use smaller quantities of chemicals and require less rinsing, for example, and factory production planning can be improved to minimize idle machine time. Perhaps most promising is improving right-first-time dyeing rates, which improves profitability and on-time delivery and substantially reduces the environmental impact associated with reprocessing fabric to correct mistakes.

Initiatives in process optimization can make a huge difference in resource use per pound of textile produced. In fact, experts estimate that reductions of up to 50 percent in water, electricity, fuel, and chemicals are possible when process improvements are combined with infrastructure improvements—more than doubling the 20 to 30 percent savings delivered by the RSI Best Practice Guide.[33]

However, this work requires a change in thinking, both on the part of management and on the factory floor, as well as a sustained and coordinated effort to investigate opportunities. It requires improved process discipline and standardization to ensure that improvements become routine. For these reasons, process improvements are sometimes a more difficult starting point for textile mills. Nevertheless, RSI strongly encourages mills to undertake these steps and in this section describes starting points where mills can most easily begin.

Managers can choose to investigate changes in these areas themselves, with in-house project teams, or to enlist the help of outside experts and consultants. Outside experts have the advantage of years of experience as well as the ability to focus exclusively on finding efficiency opportunities, whereas in-house staff typically know their processes well but have many other responsibilities. Regardless of approach, once improvements are identified, it is important to spend the time to ensure that the improvements are put into place and become routine.

IDENTIFYING AREAS FOR PROCESS IMPROVEMENTS

Here are eight promising starting points to begin investigations of process improvements that will increase profitability while reducing the environmental footprint of textile manufacturing (see Table 5):

Table 5: Process Improvements for Mills Ready to do More

Process Improvements
Undertake a failure analysis when things go wrong
Standardize optimal methods and recipes
Substitute enzymes technology in bleaching pretreatment
Investigate opportunities to reduce salt in individual reactive dyeing recipes
Increase reliance on higher fixation dyes
Improve machine utilization
Schedule colors to minimize extensive cleaning between each batch
Monitor continuously to check whether implementation of improvements is in place

Undertake failure analysis when things go wrong

Correcting mistakes and reprocessing fabric wastes a massive amount of resources. If a mill gets a color wrong, all the dyes, water, and energy used to process the fabric in the first instance can be wasted. When things go wrong, systematic failure analysis allows the mill to discover whether it has problems with particular fibers, colors, dyes combinations, machines, etc.—and whether these failures occur during particular times of day, times of year, or during particular weather conditions. Improvements can then be targeted to the key problem areas identified.

Standardize optimal methods and recipes

It is very important that mills be systematic about dyeing procedures and recipes. Successful recipes used to dye and finish a certain fabric a certain color (such as the time allotted for contact between dye and fabric, precise quantities of dyes and chemicals used, pH, temperature, etc.) should be carefully documented and rigorously repeated for repeat orders without subsequent ad hoc changes.

Substitute enzyme technology in bleaching pretreatment

Enzyme-based peroxide bleach that allows low temperature bleaching (65 °C instead of boiling) at neutral pH has recently been introduced into the market. This type of bleach reduces energy consumption in the bleaching process by an estimated 30 percent while also avoiding the use of caustic soda, a harsh chemical that alters pH. Enzymes are also reported to reduce cotton weight loss.

Reduce salt where possible in individual reactive dyeing recipes

The easiest and most promising target for reductions in chemical use is the salt used in reactive dyeing. Although the salt itself is not expensive, this improvement delivers major financial benefits because the fabric subsequently requires much less rinsing (and hence reductions in water and energy). Experts estimate that salt reductions can generate cost savings of up to 10 percent of the total process costs as well. Each dyeing recipe should be scrutinized for the salt it actually needs, rather than using generally recommended levels. Dyes should be selected that exhaust with the minimal use of salt.

Increase reliance on higher fixation dyes

Major dye manufacturing companies sell higher fixation dyes—bi-reactive dyes, for example—that have a higher affinity for fabric than average. These dyes may cost more per kilogram of dye but often cost less per ton of fabric, because of the process savings they deliver. Because more dye adheres to the fabric, less rinsing is required and less dye must then be treated in the wastewater treatment plant. It is important to calculate the full costs of using certain dyes and chemicals—including the cost/kg of dye used per square meter/ton of fabric; the pounds of auxiliary chemicals used to improve dyeing outcome; the frequency with which fabric needs to be re-run to get the color right; and the cost of water, energy, and dyes needed during re-runs—rather than just the cost of dye purchase per se.

Improve machine utilization, particularly for the most energy-intensive machines

It is common for machines to run continuously in textile mills even if they are only in use for a portion of the time. Improving use patterns of machines that consume the most energy—such as dryers (which often account for half of the energy consumption of a dyeing and finishing mill) as well as stenters, bakers, and steamers—should therefore be the highest priority for attention. Improved factory production planning can improve machine utilization and create opportunities to turn off machines, delivering greater product output for the same total energy cost. Savings will be particularly significant during low-order months with such an effort.

Schedule colors more carefully to minimize the need for extensive cleaning between each batch

In continuous dyeing operations, color changes and start-ups/stop-offs often result in time- and chemical-intensive cleanings for machines and the use of a large volume of rinsing water. A well planned dyeing schedule reduces the number of machine cleanings and the resulting pollution and water costs. The ideal sequence is to run the same color repeatedly on a particular machine. If that is not possible, it is best to group colors within families (red, yellow, blue, etc.) and then run the orders within each color family from light to darker values and from bright to duller shades. Orders from buyers should be given to the dyehouse as early as possible to facilitate optimized production scheduling.

Monitor continuously to ensure that implementation of improvements is in place

Production inputs (water, electricity, fuel, chemicals, and fabric/yarn) and outputs (product, textile waste, and emissions, etc.) should be monitored/measured at the outset to provide information for baseline performance and then monitored over time as improvements are implemented, in order to quantify results. One particularly important performance indicator in this regard is the percentage of fabrics dyed correctly the first time. It is also important to continue monitoring after improvements have been installed in order to ensure that improvements are institutionalized.

Automation

Modern technology offers important advances in improving the accuracy of the dyeing process and delivering right-first-time results, both in the laboratory and on the factory floor. In the laboratory, measuring color with instruments (spectrophotometers) is far more reliable than using the naked eye. Automatic dosing pipettes are far more accurate than manual glass pipettes. On the factory floor, automated dye dispensing systems ensure that the correct amount of dye is delivered each time. Similarly, computer technology has enabled dyeing machines to be precisely controlled according to a predetermined set of process specifications. These systems can accurately control temperature, the timing of chemical feed to the dye machines, bleach ranges, water additions, pH, cycle times, and more. Once a predetermined optimized process is programmed into the computer, these tasks can be handled automatically, dramatically improving right-first-time processing. By greatly improving accuracy and repeatability, automation makes a major contribution to improvements in the quality of output, with less re-work and fewer defects. These improvements in turn reduce the water, energy, and chemicals consumed per unit of product produced, reducing the environmental footprint of the fabric mill.

Good Housekeeping

Many textile mills can take significant steps toward reducing waste and cost by implementing small changes in behavior, regardless of whether they also implement the RSI best practice list. These good housekeeping initiatives require little or no investment beyond improved management and attention to detail, but did not qualify as best practices because their savings are difficult to quantify or because they promise only modest environmental benefits.

However, the recommendations are easy to understand and implement and should prove to be an appealing starting point for some mills. Adopting these quick and easy opportunities will help mills develop a "clean production" mentality that can translate into the managerial commitment needed to support more substantial improvements. And they can have a big impact: as much as 5 to 10 percent savings in resources in the experience of some experts.[34]

The RSI factory audits found nearly a dozen promising, easy to implement opportunities for improved housekeeping at the mills assessed:

- **Unmarked stored goods.** Confusion about unmarked stored goods can lead to the selection of the wrong chemicals. Mills should also mark clearly where the different goods are to be placed.
- **Poor storage practices.** Materials that are stored in a workshop have a higher risk of being damaged or contaminated. Instead, it is good practice to demarcate a special storage area in the workplace, raise the floor level of the storage areas, and improve management there so as to reduce breakage and leakage. Dyes should be stored in a centralized area in dry and clean conditions.
- **Poor chemical inventory management.** A first-in, first-out system will reduce waste from expired shelf life of certain chemicals.
- **Unclean work sites.** Unclean work sites can lead to rework through contamination of process baths or textile products. Regular cleaning of the workspace should be the responsibility of the staff at each workstation.
- **Leaks and running water.** Water is commonly wasted when hoses or cooling water are left running even after machinery is shut down. Rather than relying on workers to reduce water use, low-flow and shut-off valves should be installed on hoses, and thermally-controlled shut-off valves can be installed on process units.
- **Inefficient and inconsistent bulk chemical preparation.** Bulk chemicals are best prepared in a solution that is pumped to dyeing machines as needed.
- **Inadequate scoops.** Dyeing chemicals should be taken only with scoops that are dedicated to each separate color to avoid cross-contamination.
- **Preparing excess chemical solutions.** Only required amounts of chemicals or prepared solutions should be taken to the production areas, with minimal surplus.
- **Equipment (e.g. scales used to weigh dyes and chemicals) that is not calibrated.** Unreliable data leads to wrong decisions and poor outcomes. It is important to calibrate equipment and monitor quality of measurements by weekly checks of the recorded data. Scoops of different sizes and buckets with marked volumes are also very helpful to improving measurement accuracy.
- **Poor boiler blow-down practices.** Boiler water contains impurities that increase in concentration over time, eventually forming a sludge that impairs boiler efficiency. Facility managers should optimize blow-down (water bleed-off) frequencies. A boiler efficiency study should be conducted annually to optimize the boiler system.
- **Wasteful lighting.** Switching lights off when they are not in use and replacing old, inefficient bulbs with new energy-saving models can substantially reduce electricity costs. It is helpful to measure brightness in different areas of the mill and remove unnecessary light tubes as well.

Printing Improvement Opportunities

At mills that print onto fabric, printer paste represents a big cost due to the high price of the paste. Printer paste can also be a large and unnecessary source of oxygen-depleting pollutants and color-loading to the wastewater treatment plant and the receiving water body. A few easy, inexpensive measures, taken at almost no cost, can save paste and reduce the load of waste paste that needs to be treated:

- **Clean rotary printer with squeegee.** After printing, some printing paste remains in the cylinders. This printing paste is usually flushed out in the cleaning process and ends up in wastewater. The method increases pollution load at the treatment plant. This load can be reduced by using a specially designed squeegee to manually remove printing paste from the cylinder before rinsing. The paste can be returned for reuse. Such squeegees can be purchased at a very low cost.
- **Use a closed loop printer cleaning system.** At the end of the printing process the printer stations need to be rinsed. This typically occurs via an open system where the printing station is flushed with water that is then sent down the drain. Water can be saved by building a closed system, in which rinse water is recycled back through the system, instead of being discarded as wastewater after the first pass. With this measure, mills could reduce water used for printer cleaning by 60 percent, compared to the traditional rinsing method.
- **Use small paste applicators when printing samples.** Sample printing requires only small amounts of printing paste. When the full pumping system is used to deliver paste to a sample, a relatively large amount of paste remains in the pumps, hoses, and cylinders. This paste is flushed out and wasted during the cleaning process. This problem is easily addressed by using a smaller manual paste applicator for printing samples. These applicators can be developed in-house or purchased at a low cost.

Appendix A: Description of Mills

Five Chinese textile mills of various sizes participated in the Responsible Sourcing Initiative. All worked with cotton fiber or fabric. Table A gives an overview of the production processes undertaken in the participating mills. RSI focused only on opportunities for improvement in dyeing/finishing yarn and fabric (both woven and knitted) where the largest opportunities for improvements can be found. Resources required for knitting or garment manufacturing were subtracted out of the total resource use of integrated mills in order to fairly compare usage per unit of product for dyeing and finishing.

The five fabric mills differed in the way they procured energy for production. Some mills produced their own steam with coal-fired boilers and purchased electricity from the grid. Others purchased steam from an off-source location or co-generated their own electricity from their own boilers. RSI benchmarked resource use per ton of production by converting all the forms of energy consumption (electricity, steam, and heat value in thermal oil) into standard coal equivalents. These figures were then added together to get the total coal equivalent used for dyeing and finishing fabric.[35]

Table A: Production Processes in the Five Companies

	Yarn Dyeing	Knitting	Fabric Dyeing & Finishing	Fabric Printing	Garment Manufacturing
AC	✓				
LS		✓	✓	✓	✓
KH	✓	✓	✓		✓
NX			✓	✓	
RB			✓		

AddChance (AC)

Zhangjiagang, China

ZJG AddChance is a medium-sized textile company engaged in dyeing of bobbin yarn and hank yarn in batch equipment. Its designed production capacity is 18,000 tons of bobbin yarn per year, and 6,600 tons of hank yarn per year. Due to economic conditions, the company was working half time during the RSI efficiency audit, and its actual annual output was only 6,800 tons of bobbin yarn and 2,000 tons of hank yarn.

Note: AddChance generates its own steam by coal-fired boiler, and purchases its electricity from the grid.

Laosan (LS)

Changzhou, China

Laosan is a large integrated textile mill with 5,000 employees engaged in knitting, dyeing, embroidering, and garment manufacturing. Its maximum production capacity is 20,000 tons of knitted fabric (and 45 million pieces of clothing) per year. The company dyed 12,217 tons of textiles in 2008, the year of the RSI assessment. Most textiles are processed in batch dyeing processes, and a smaller quantity of textile is processed in continuous processes.

Note: Laosan does not generate its own steam, but instead buys steam from an outside source. It uses coal only for heating oil, and purchases electricity from the grid. RSI estimated the amount of coal used to generate the purchased steam in creating the LS coal benchmark.

Nanxin (NX)

Foshan, China

Nanxin is a small textile company with 380 employees engaged in dyeing and printing of woven textile. Although its maximum production capacity is about 7,500 tons per year, the actual output was about 5,000 tons per year during the RSI assessment.[36] Nanxin processes fabrics in continuous processes.

Note: Nanxin has its own co-generation boilers, which provide the factory with both electricity and steam. It also uses a coal-fired boiler for heating oil. RSI back-calculated the amount of coal used for production from the mill's steam values, so that the baseline coal use was comparable in type to other mills. In addition, Nanxin's incoming water purification and wastewater treatment are outsourced from a nearby factory. This accounts for the higher water costs per liter reported by the firm.

Kam Hing (KH)

Guangzhou, China

Kam Hing is a large integrated textile mill with about 3,860 employees engaged in knitting, dyeing, and garment manufacturing. The mill produced 45,000 tons of knit fabric and 12,000 tons of yarn in the year of the RSI assessment. Most textiles are processed in batch dyeing processes, and a smaller amount of textile is processed in continuous processes.

Note: Kam Hing has its own coal-fired co-generators that provide the factory with both electricity and steam. It also has a thermal oil boiler in the factory. All the consumption numbers are based only on textile-dyeing-process-related consumption.

Redbud (RB)

Changshu, China

Redbud Co. Ltd. is a medium-sized factory with more than 1,000 employees engaged mainly in woven fabric dyeing and fine jute fiber processing, clothing, and spinning. Although the maximum dyeing production capacity is 45.7 million meters per year, the actual annual output during the RSI assessment was 36.6 million meters (roughly 10,000 tons) of fabric in 2007.[37] Most textiles are dyed in continuous dyeing processes.

Note: Red Bud produces its own steam by coal-fired boilers and purchases electricity from the grid. It also has a thermal oil boiler.

Appendix B:
Best Practice Selection

To choose the best practices among the 33 that we assessed in the study, we categorized practices based on three factors: cost, payback, and environmental impact:

Cost:
- Low investment < $15,000
- Medium $15,000 - $37,000
- High > $37,000

Payback:
- Immediate < 1 month
- Quick 1-4 months
- Medium 4-8 months
- Long > 8 months

Environmental impact:

Water (tons water/ton fabric)
- High > 5 tons
- Medium 1.5 to 5 tons
- Low < 1.5 tons

Coal (kg/ton fabric)
- High > 50
- Medium 10-50
- Low < 10

Electricity (kWh/ton)
- High >75
- Medium 10-75
- Low < 10

These criteria were applied to 33 potential efficiency measures and clean production practices, identified in Table B.

Table B: Best Practice Candidates

	Companies	AC	LS	NX	KH	RB
1	Insulate steam flanges, valves and pipes	✓	✓	✓	✓	
2	Install of meters	✓	✓	✓	✓	
3	Reuse condensate	✓	✓	✓	✓	✓
4	Optimize of chemicals consumption	✓	✓	✓	✓	✓
5	Maintenance and leak fixing	✓	✓	✓	✓	
6	Counter Current rinsing	✓	✓		✓	
7	Further drying of sludge before burning	✓	✓		✓	
8	Recycle heat from hot rinse water	✓	✓		✓	
9	Reduce the re-work	✓	✓		✓	✓
10	Optimize air compressor system	✓	✓	✓	✓	
11	Improve dye selection	✓	✓	✓		
12	Reuse heat from boiler stack			✓	✓	✓
13	Good Housekeeping	✓	✓			✓
14	Reduce printing paste waste (squeegee)		✓	✓		
15	Use smaller hand pump for sample printing		✓	✓		
16	Install closed loop printer cleaning		✓	✓		
17	Steam trap maintenance	✓		✓		
18	Voltage at river water inlet pumps				✓	
19	Improve dust management		✓			
20	Printing paste production		✓			
21	Preheat combustion air	✓				
22	Optimize boiler blow down	✓				
23	Install coal pre-screening facility	✓				
24	Install VSD's	✓				
25	Y-series motors -> YX series motors	✓				
26	Re use cooling water from singeing machine			✓		✓
27	Caustic recovery			✓		✓
28	Improve lighting			✓		
29	Cold pad batch pretreatment					✓
30	Reuse bleaching water					✓
31	Reuse cooling water from preshrink machine					✓
32	Reuse cooling water from air compressor					✓
33	Use coal ash to pretreat caustic wastewater, sell resulting sludge to make bricks					✓

Endnotes

1 GB 17167-2006. General principle for equipping and managing of the measurement of energy in industry.
2 Specifically the three levels of meters is compulsory for mills whose total energy consumption is bigger than 10,000 tons standard coal.
3 Personal communication with Wilkie Wong, Esquel Group, supplemented with research with various meter company representatives.
4 Personal communication with Makis Kasnakidis, Intertrad Corporation, which offers this equipment and service. www.intertradgroup.com.
5 One best practice, capturing heat from hot rinse water, exceeded this range at one mill.
6 Because mercerizing processes are relatively uncommon, we do not include reductions from reuse of mercerizing process water in the low end of the range of the RSI Best Practice water savings estimate. It is included in the high end.
8 Chen Liqiu *Textile dyeing and finishing industry energy saving and pollution reduction technical guidance*, Chemical Industry Press. ISBN. 978-7-122-03585-1. Oct. 2008. p 560. In Chinese.
9 Based on 8000 working hours per year .
10 BSR Energy manager Training Program Material, August 26-27th 2009, Wal-Mart 2009 Energy Efficiency Program
11 BECO Institute for Sustainable Business. Draft report Responsible Sourcing Initiative of the NRDC: Shunda Nanxin Dyeing Factory Ltd Company, Foshan. Aug 29, 2009.
12 S. Barclay and C. Buckley. 1993. Waste Minimization Guide for the Textile Industry – A Step Towards Cleaner Production, Volume III. In: UNEP/IEO ICPIC International Cleaner Production Information Clearing House.
13 Cooling water from jet dyeing machines could save an additional 5-15 tons water per ton of fabric, according to Arthur Welham of Dyehouse Doctor. Personal communication. Nov 16, 2009.
14 Chen Liqiu *Textile dyeing and finishing industry energy saving and pollution reduction technical guidance*, Chemical Industry Press. ISBN. 978-7-122-03585-1. Oct. 2008. p 124. In Chinese.
15 Guangxin(Changzhou) Textile Dyeing Co.Ltd Energy saving and pollution reduction project. In Chinese. Copy available at NRDC.
16 BECO Institute for Sustainable Business. Draft Report. Responsible Sourcing Initiative of the NRDC: Shunda Nanxin Dyeing Factory Ltd Company, Foshan. August 29, 2009.
17 Personal communication with Mr Jiang Weili, Senior Engineer, Jiangsu Academy of Environmental Sciences, Nanjing, China. November 27, 2009.
18 Chen Liqiu *Textile dyeing and finishing industry energy saving and pollution reduction technical guidance*, Chemical Industry Press. ISBN. 978-7-122-03585-1. Oct. 2008. p 20. In Chinese.
19 It is difficult to recover heat from stack gas of coal-fired boilers because of corrosion problems. For this reason, we do not include reductions from recovering heat from smoke stacks in the low end of our reduction range.
20 Some common fuels and their energy contents are shown in the table below.

Fuel	Energy value		
	Joules		BTUs
Coal [1]	15-27	mj/kg	8000-14000 btu/lb
Natural gas [2]	37-41	mj/ft3	1000-1100 btu/ft3
Wood [3]	18-22	gj/ton	7600-9600 Btu/lb

Sources:

(1) http://hypertextbook.com/facts/2006/LunChen.shtml
(2) http://hypertextbook.com/facts/2002/JanyTran.shtml
(3) http://bioenergy.ornl.gov/papers/misc/energy_conv.html

21 E-Textile Toolbox, "Heat Recovery from Process Water." www.e-textile.org.reviewmeasure.asp?OptiD=206&lang=ind.
22 Personal communication with Bas Kothius, BECO Institute for Sustainable Business.
23 BECO Institute for Sustainable Business. *Draft Report: Responsible Sourcing Initiative of the NRDC: ZJG Addchance Dyeing and Finishing Company, ZhangJiaGang,* p 25. Draft dated July 22, 2009.
24 http://www.e-textile.org/previewmeasure.asp?OptID=2274&lang=ind.

25 Chen Liqiu *Textile dyeing and finishing industry energy saving and pollution reduction technical guidance*, Chemical Industry Press. ISBN. 978-7-122-03585-1. Oct. 2008. P579 In Chinese.
26 *Ibid.* p 579. In Chinese.
27 *Ibid.* p 579. In Chinese.
28 Knitting operations consume a large amount of electricity but were not evaluated in RSI.
29 BECO Institute for Sustainable Business. Draft Report: Responsible Sourcing Initiative of the NRDC: ZJG Addchance Dyeing and Finishing Company, JhangJiaGang. July 22, 2009.
30 Personal communication with Arthur Welham, Dyehouse Doctor, Oct 31, 2009.
31 E-Textile Toolbox. "Regular Maintenance of the Compressed Air System." www.e-textile.org/previewmeasure.asp/OptD=22&&lang=ind.
32 Thank you to Phil Patterson, Color Connections, for his helpful classification of improvement initiatives in the textile sector.
33 Personal communication with Intertrad Group. November 25, 2009.
34 BECO Institute for Sustainable Business. 2009. Final Report: Responsible Sourcing Initiative. Cleaner production Opportunity Assessments in Four Chinese Textile Companies. p 6.
35 1 tce= 1 ton standard coal equivalent = 7,000,000 kcal = 29.3076 MJ. Conversion coefficients are as follows: 1 ton raw coal = 0.7143 tce; 1*10,000 Kwh = 4.04 tce; 1 tce = 6.5 ton steam.
36 The company measures its woven production in yards, which is a length unit. RSI converted length to weight for the purposes of establishing a consistent baseline using a conversion factor provided by the company: 150-350g.yard. This causes a large range in the calculation of the production quantities. In this report we have used a value of 250g/yard for conversion of area to weight.
37 Weight conversion was done as described for Nanxin.

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