NRDC ISSUE PAPER

DECEMBER 2013
IP:13-03-C

NRDC Guide to Metering in Textile Mills

About NRDC

NRDC (Natural Resources Defense Council) is a national nonprofit environmental organization with more than 1.4 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, Chicago, Montana, and Beijing. Visit us at www.nrdc.org.

NRDC's policy publications aim to inform and influence solutions to the world's most pressing environmental and public health issues. For additional policy content, visit our online policy portal at www.nrdc.org/policy.

About RESET Carbon Ltd.

Based in Hong Kong and serving Greater China as well as the Asia-Pacific Region, RESET is a consultancy firm aiming to help organizations achieve real value from carbon and energy reductions by providing climate change and energy management solutions. RESET's energy systems engineers and clean development accountants serve as the efficiency assessment experts in NRDC's Clean by Design program. RESET works closely with dyeing and finishing mills across China and provided the cost and savings estimates for metering equipment and installation that are found in this Guide to Metering.

NRDC Director of Communications: Edwin Chen
NRDC Deputy Director of Communications: Lisa Goffredi
NRDC Policy Publications Director: Alex Kennaugh
Design and Production: www.suerossi.com

TABLE OF CONTENTS

ABOUT THIS GUIDE

Clean by Design is an innovative program initiated in 2009 by the Natural Resources Defense Council (NRDC) aiming to use the buying power of multinational apparel retailers and brands as a lever to reduce the environmental impacts of their suppliers abroad. One of Clean by Design's major initiatives is a partnership program between NRDC and seven multinational companies and brands—Nike, Levi's, the Gap, Walmart, Target, H&M, and Li & Fung–that focuses on improving process efficiency to reduce waste and emissions in fabric mills and dye houses, a key link in the supply chain with huge environmental impacts.

The first step necessary to begin improving factory efficiency—the activity that underpins all other opportunities recommended by the Clean by Design program—is to measure consumption of water, steam, and electricity in total for the entire factory and at the process and major equipment levels. These measurements allow a fabric mill or dye house to create a baseline of resource consumption from which hot spots of resource use can be identified, and against which improvements can be measured. This information could also be used by brand customers to compare the relative efficiencies of suppliers, enabling them to use environmental performance as a factor in purchasing decisions.

The purpose of this guide is to provide decision-makers at textile factories, suppliers, and brands with practical information about meters for water, steam, electricity, and compressed air. Section 2 provides perspective on the role of metering in factory management. Section 3 reviews metering hardware, scope of application in a fabric mill or dye house, and typical costs. Section 4 lists considerations for developing a metering strategy, taking into account how the data will be used. This section also reviews the Chinese regulatory requirements for metering. The guide concludes with two examples that demonstrate the development of a metering plan, the selection and placement of meters, and costs of the system. RESET Carbon Ltd. provided estimates of metering equipment and installation costs for this guide, based on its consulting experience in the Greater China area.

INTRODUCTION

THE CLEAN BY DESIGN PROGRAM

Manufacturing practices in less developed countries tend to use resources less efficiently than in the developed world. These process inefficiencies waste money by using more energy, water, and materials than necessary. There are plenty of opportunities to improve efficiency in manufacturing processes while preserving product quality. And by reducing resource consumption, facilities can both save money and improve the environment.

NRDC's Clean by Design program promotes these opportunities to increase efficiency (in energy, water, and chemical usage) and thereby reduce a factory's environmental footprint while saving it money. Working with major apparel retailers and brands, Clean by Design has conducted on-site assessments of multiple fabric mills in China and identified a range of technical measures with rapid cost-saving potential that are replicable across different mill sites. NRDC has designated 10 of these efficiency measures as Ten Best Practices and is working with brands and mill partners to further promote the adoption of these practices in mills. The ultimate aim is for multinational retailers and brands to incorporate efficiency and other environmental performance measures into their purchasing decisions.

THE BUSINESS CASE FOR ENERGY AND WATER EFFICIENCY

For mills, improved energy and water efficiency can mean reduced costs and improved relationships with customers seeking to improve the environmental sustainability performance of their supply chains.

Reduced costs

Because factory energy bills are usually significantly higher than water and wastewater treatment costs, energy efficiency is often the initial focus of cost-saving measures. However, even where mills are not directly charged for water, the hidden costs of water—that is, the costs of pumping, pretreating/softening for use in processes, and treating wastewater—can add up. Where process water is reused, there can also be considerable savings in chemicals that are also reused or recycled. Since energy costs and water costs are expected to increase in China and other major sourcing markets, efficiency improvements made today will continue to pay a dividend in the future as prices rise.

NRDC's experience with environmental audits has shown that textile mills processing 2,000 to 20,000 tons of fabric per year can reduce resource consumption and save between 650,000 RMB and 4 million RMB annually, with aggregate paybacks usually in less than 12 months. This represents the initial savings potential from a range of simple, low-capital investment measures; even greater savings can be achieved over the longer term. To learn more about these savings opportunities, see NRDC, Responsible Sourcing Initiative: Ten Best Practices, 2013.

Customer relationships

Apparel retailers and brands are under increasing public pressure to improve the environmental performance of their supply chains. Fabric dyeing and finishing mills are central to any effort to improve the sustainability of the apparel supply chain, as these facilities consume far more resources and have greater potential to emit pollution than do the factories where apparel is cut and sewn. A number of leading brands have therefore begun the process of engaging their fabric vendors to explore improving the sustainability of products and processes, especially through improved energy and water efficiency at dyeing and finishing mills, where greater resource use also means a greater potential for cost savings.

The seven retailers and brands participating in the Clean by Design initiative are examples of this engagement. NRDC will continue to work with these brands to deepen their engagement with fabric suppliers and to document the energy, carbon, and water saved through the efficiency measures taken.

Brands are also working with one another to find common ways of measuring supplier performance on sustainability issues. Among these multi-brand collaborations is the Sustainable Apparel Coalition (SAC), whose members represent more than 30 percent of apparel sales worldwide. SAC, with NRDC's involvement, has developed a facility index that will provide apparel brands with a common tool for benchmarking suppliers—including mills—on sustainability issues, including water and energy efficiency performance.

THE ROLE OF METERING

Accurate measurement of on-site energy and water use is critical in accounting for current costs and recognizing the benefits of efficiency measures. However, NRDC's work has revealed that many Chinese textile mills are not currently metering their energy and water use effectively. The following two conditions are found in the majority of mills surveyed:

- **Lack of metering infrastructure.** While almost all mills have metering of some kind, many have not installed enough meters to properly understand patterns and trends of energy use in different parts of the mill. It is common for a plant to have a single, plant-level water and gas meter, but no additional submeters anywhere in the factory. While plant-level data are essential to track trends like gallons of water used per cubic meter of fabric processed, it cannot identify where waste might be occurring.

- **Metering infrastructure with inadequate collection and/or processing of data.** Some mills have extensive metering infrastructure but fail to collect and analyze the data from these systems adequately. Data collected manually are generally collected infrequently, limiting opportunity for data analysis. As a result, mills will not have good insight into how equipment and processes are performing and whether efficiency levels are improving or deteriorating.

From a textile mill perspective, there is no "correct" level of metering or a one-size-fits-all solution. Meters should be deployed strategically to deliver data and information that support engineering and management goals. Meters can be used to:

- Provide a simple overview of main patterns of energy and water use to evaluate overall energy efficiency of production and report to stakeholders (such as customers).
- Provide detailed data on energy and water use to customers seeking to understand more about the life cycle performance of their products.
- Provide a baseline of energy and water use in specific workshops and by specific equipment before efficiency measures are put in place, in order to evaluate the effectiveness of those measures.
- Evaluate new equipment to ensure it is performing to manufacturer specifications.
- Provide real-time data on performance of existing energy- and water-intensive processes and equipment to evaluate whether they are being operated efficiently and without equipment malfunction. Similar equipment or processes running in different workshops can be benchmarked against each other, or against a database of historical resource use to further increase performance insight.
- Use portable temporary meters to spot-check performance of subsystems where issues are suspected and validate other meter and billing data.
- Integrate benchmark resource consumption with other information systems (e.g. customer orders) for estimating and forecasting upcoming energy demands and energy production/consumption needs.
- Use intelligent control systems to integrate sensor data such as external air temperature, indoor temperature, etc to adjust consumption expectations and goals.

BARRIERS TO METERING

In Clean by Design factory assessments, NRDC has found that systematic energy and water management is not often a priority and therefore is not widely practiced in Chinese textile mills. The lack of attention has several main causes:

- Lack of visibility of the cost-savings potential of water and energy efficiency, particularly when compared with other opportunities to reduce costs (e.g., changes in raw material inputs and labor).
- Lack of confidence that estimated cost savings, where identified, can be realized.
- Small magnitude of cost savings. If a major innovation program is required to save several hundred thousand RMB in a large mill, this may not compete successfully with other uses of capital being considered by the business decision-makers.
- Lack of appropriate technical skill sets on-site. In particular, engineers on-site may have insufficient training in industrial process engineering and may therefore downplay the potential efficiency opportunities that are not well understood.
- Artificially low prices for water and coal, which seriously undermine the return on investment of some important efficiency measures.
- Lack of incentives for buyers to require such information in order to track performance of their suppliers.

Metering represents a capital cost of as much as 200,000 to 500,000 RMB for a midsize mill to purchase and install a state-of-the art system, although the price tag can be much lower for more modest systems. Metering does not deliver energy savings directly but facilitates energy and water management that will lead to savings in the future. As such, the return on a metering investment is reliant upon the success of subsequent water and energy management projects, and this can make mills more reluctant to invest capital. Mill managers who lack confidence in metering systems or in the ability of management to follow through and respond effectively to problems revealed by meter data are understandably leery of investing money in mill meter improvements. However, meters are critical to the collection of quantitative information needed for the mill to manage its efficiency and for stakeholders to evaluate its performance. What gets measured gets improved, and absent adequate resource utilization data, it will be impossible for even a highly motivated plant manager to undertake significant resource efficiency work.

This Guide provides information about metering technology options, offering an overview of the main elements to consider in developing a metering strategy and integrating it into an ongoing energy and water management program.

METERING AND WATER AND ENERGY MANAGEMENT

Metering is most effective—and provides the greatest value for money—as part of a water and energy management system operated at the site level. Simply put, a management system ensures that the investment in the meters is recouped through proper follow-through and implementation of efficiency measures that will save significant money.

An energy/water management system provides a framework for integrating resource performance into a mill's management practices, so that investments of time and capital in improving efficiency will result in measureable business benefits.

A typical energy/water management system structure is shown in Figure 1.

Figure 1: Overview of an energy/water management system structure

A successful energy/water management system will have the following characteristics, with metering a critical aspect:

Senior management commitment. This will ensure formal accountability for energy/water performance at a senior management level. *Metering systems should be structured to deliver clear high-level energy and water performance summaries to senior management.*

Energy/water champion. A designated individual must be responsible for driving energy and water management programs forward and coordinating collaboration among different parts of the mill operation. *Metering systems should be configured to provide easily summarized and appropriately detailed performance information to the energy/water champion.*

Policy and targets. A mill's approach to managing energy and water should be formally articulated, and measureable targets must be set to drive performance improvements. *Metering systems will need to be structured to ensure that data provided is sufficient to accurately report against quantitative targets.*

Energy efficiency audits or assessments. Third-party on-site investigations provide mills with a clear list of individual energy/water efficiency opportunities and the associated costs and paybacks. *Audit results will be improved if metering is already in place and providing auditors with more detailed performance data. Auditors may also deploy temporary meters to enhance audit results.*

Action plan. A timetable of planned energy/water efficiency improvements, with clear staff accountabilities, is based on efficiency opportunities and designed to deliver the targets. *Development and deployment of a metering strategy is usually an early priority in an energy management action plan.*

The ISO 50001 Standard

Detailed information on the implementation of an energy management system is contained within the ISO 50001 energy management standard.

ISO 50001 was launched in 2011 with the goal of supporting organizations seeking to improve the quality of their energy management. It provides a framework for integrating energy performance into an organization's management activities. The standard requires suppliers to develop an energy management system that includes elements such as clear policies and targets, effective collection and use of performance data, and a continuous improvement program.

ISO 50001 can be applied internally or with third-party certification as an option for organizations seeking formal recognition of their achievements. More information is available at www.iso.org/iso/iso_50001_energy.pdf.

METERING HARDWARE

This section gives an overview of hardware solutions available to help mills measure energy and water consumption.

ELECTRICITY METERS

An electricity meter measures the quantity of electrical energy consumed by a particular device, a series of devices, or an entire building or facility. Two major options are available: low-cost, traditional mechanical meters; or electrical "smart" meters, which can provide more information on power usage—and, crucially, also can be read remotely, to allow centralized capture of data and processing of energy management information.

Mechanical kWh meter

Often found in Chinese textile mills with a limited approach to energy management, mechanical meters show accumulated kilowatt-hours (kWh) but do not facilitate data logging unless monitored continuously.

Scope of Application

This type of meter is most suitable for areas where meter readings are not needed at frequent intervals or for equipment where energy management is not taking place and where usage is not linked to production. Examples include:

- Canteens, dormitories, and offices
- Individual minor power use equipment, such as extraction fans and water pumps
- External lighting

Electrical smart meter

The electrical smart meter records consumption of electrical energy in intervals of an hour or less and has the capability to electronically communicate the information for monitoring and billing purposes or to a networked on-site energy management system. Its accuracy is comparable to that of the mechanical type.

Scope of Application

Smart meters can be used reliably across most electrical equipment on-site in a textile mill, either field-mounted or located in main electrical switchboards. The Networking section below discusses how smart meters can be integrated into a networked energy management system.

Current transformer (CT)

Where any meter or monitoring device already exists along power lines, a current transformer (CT) will be in place to provide power to the metering instrument at a lower voltage than is in the line itself. In many cases, to save cost, an existing CT can be retained and reused when a metering point is upgraded. Where new points are added, a CT and meter will need to be purchased and installed.

Comparison

Figure 2: Comparison of electrical metering components

	Price (RMB/unit)	Accuracy +/- %	Installation and Maintenance	Life Span
Mechanical	150 – 450	2.0	Simple	25 years
Smart	800 – 2,000	0.5 – 1.0	Simple, but requires higher skill than mechanical meters for network connections	15 years
CT	150 – 400	0.1 – 0.5	Simple	25 years

STEAM FLOW METERS

Steam is challenging to measure. It contains both condensed hot-water droplets and gaseous vapor and is thus considered a two-phase flow. Nonetheless, there are many types of flow meters suitable for steam applications, including:

- Orifice type
- Vortex shedding
- Variable area
- Pitot tube
- V-Cone
- Turbine
- Direct in-line variable area (DIVA)

Each of these flow meter types has its own advantages and limitations. Orifice and V-cone are usually most suitable for use in textile mills, given the steam pressures, temperatures, and flow rates encountered there.

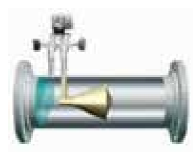
Orifice flow meter

Orifice flow meters are designed for measuring flows at pressures up to 30 bar[1] and temperatures to 300°C. Typically, mills operate with process heating steam pressures between 6 and 10 bar and with saturated steam temperatures up to around 160°C. The orifice flow meter needs adequate space to be correctly installed: Typically there should be a straight pipe whose length is more than 10 times the pipe diameter upstream of the meter, and a pipe whose length is 5 times the pipe diameter downstream of the meter, for the meter to perform to its accuracy specifications.

Scope of Application

Orifice flow meters are accurate enough to be used for both energy management and billing purposes, for example in the following locations:

- Boiler rooms
- Main steam pipes
- Branch steam pipes
- Equipment that makes heavy use of steam (providing there is sufficient space for installation).



V-Cone flow meter

V-Cone flow meters are designed for measuring flows of air or other gases (especially air with water) at pressures up to 100 bar and temperatures to 800°C. They are more expensive but also can be a little more accurate than orifice meters and therefore suitable where precise commercial billing is required. They are not often encountered in Chinese facilities.

If used in a main pipe, the V-Cone flow meter will ideally have a bypass provision to allow maintenance to be performed without shutdown of the supply.

Scope of Application

V-Cones are best used when highly accurate data are required, as in:

- Measuring equipment efficiency performance to determine savings, for example after adding insulation or a heat-recovery retrofit.
- Testing new equipment and installations against claimed performance, for example validating the declared steam consumption of a new dyeing process tank.

Comparison

Figure 3: Comparison of steam meters

	Price (RMB/unit)	Accuracy +/- %	Installation and Maintenance	Life Span
Orifice	5,000 – 8,000	1.0 – 2.0	Easy—Can usually be clamped between existing pipe flanges	15 years
V-Cone	15,000 – 30,000	0.5 – 2.0	Hard—Shutdown is required	15 years

WATER METERS

Metering for raw, soft, and hot water, as well as condensate and wastewater, is needed for a full understanding of water use. These measurements can also aid in the understanding of energy system performance and specific process performance. Three major types of water meters are applicable in textile mills.

Mechanical water meter

Mechanical water meters indicate accumulated flow. Pulse-type models also include mechanically operated switch contacts to allow remote "pulse counting" of flow rate where remote reading is required.

Scope of Application

Mechanical water meters are commonly used for small-volume water measurements such as in offices and dormitories. They must be sized to suit flow rate, for accuracy and to avoid pressure drops. Because maintenance entails complete removal, a bypass pipe is recommended if installed in applications where water shutdown would interrupt production.

Electro-magnetic flow meter

These meters display both flow rate and accumulated volumetric flow.

Scope of Application

Electromagnetic meters are suitable for measuring flows in large pipes and are accurate enough to support billing. Suitable locations include:

- Main water pipe
- Branch fresh water pipe
- Branch hot water pipe
- Equipment freshwater

Ultrasonic flow meter

An ultrasonic flow meter measures the velocity of a liquid or gas (fluid) by using ultrasound and the Doppler effect. They can be cheaper than the electromagnetic type of meter, and clamp-on variants are available that allow installation without shutdown. However, the accuracy of ultrasonic meters is generally not high. The product also needs to be matched to the pipe wall thicknesses and pipe diameters.

Scope of Application

Ultrasonic meters are typically suitable for measuring noncritical flows in textile mills, because although installation and maintenance are easy, accuracy can be limited. They also offer the most practical solution for contaminated water or water with high suspended-solid content because there is no physical contact between the water and the meter.
These meters are not suitable for situations where billing-quality data are desired. The meters can also lose accuracy in situations where the water flow does not fill the pipe, which means that use in drainage pipes or some water recycling pipes should be considered on a case-by-case basis. Suitable locations include:

- Branch freshwater pipe without billing
- Equipment freshwater
- Branch hot water pipe

Comparison

Figure 4: Comparison of water meters

	Price (RMB/unit)[2]	Accuracy (pipe full) +/- %	Accuracy (pipe not full) +/- %	Installation and Maintenance	Life Span
Mechanical[3]	1,000	5	5	Hard—Physical removal requires that flow be halted, unless bypass is installed	10 years
Electromagnetic	16,000 – 25,000	0.2 – 0.5	1 – 3	Hard—Physical removal requires that flow be halted, unless bypass is installed	15 years
Ultrasonic	6,000 – 8,000	1	10	Easy—Mounted externally	15 years

COMPRESSED-AIR FLOW METERS

Compressed air is very expensive to produce and therefore worth measuring as accurately as possible, since inefficiencies can be substantial. It is recommended to install one main flow meter for every compressed-air system, and also to install electrical smart meters for compressors so that energy use per cubic meter of compressed air produced can be tracked. Leaks can also be tracked by observing compressed-air flow when production is shut down. Two main options are available for compressed-air metering:

Orifice flow meter

Orifice flow meters are designed for measuring flows of compressed air at pressures up to 30 bar (ample for typical mill use at 6 to 8 bar). As with steam, orifice flow meters need a relatively large amount of space for installation to achieve accuracy.

Scope of Application

Orifice meters can be used for almost all compressed-air systems for energy management purposes. Suitable locations include:

- Main compressed-air pipe
- Branch compressed-air pipe
- Equipment compressed air

Vortex flow meter

Vortex meters work by placing a bluff body (called a shedder bar) inside the pipe. Small vortices will form behind the object, and a sensor tracking these vortices can determine rate of flow.

Scope of Application

Vortex meters are highly accurate and suitable for use where data are used for billing purposes or where equipment is being tested. Pricing, however, is usually too high for widespread use. Suitable applications include:

- Main branch compressed-air pipe
- Compressed-air metering for equipment consuming large amounts of energy

Comparison

Figure 5: Comparison of compressed air meters

	Price (RMB/unit)[2]	Ease of use	Accuracy +/- %	Installation and Maintenance	Life Span
Orifice	5,000 – 8,000	Hard	2.0 – 3.0*	Easy—Can usually be clamped between existing pipe flanges	20 years
Vortex	15,000 – 20,000	Hard	1.0 – 2.0	Hard—Invasive maintenance required	15 years

PORTABLE METERS

Temporary portable meters can be deployed for cheap, one-time sample measurements to assess and predict potential savings and to validate the approximate accuracy of permanent meters if there is a suspected malfunction. Portable meters can also be used in advance of a permanent metering program to gain an initial understanding of consumption patterns in specific workshops or by energy-intensive equipment, although the limited accuracy of the meter technology and the short-term sampling period need to be considered when reviewing the results. Portable meters are not available for measuring steam, although steam flow can be estimated by temporarily diverting related condensate, collecting for a known time, and then weighing to check the approximate flow rate.

Clamp-on electricity meter

The clamp-on meter can be easily deployed in different parts of the electricity system.

Scope of Application

Low accuracy generally makes these meters unsuitable for detailed efficiency evaluations or for measuring small system loads. They are most suitable for error checking—identifying and diagnosing performance problems—and for generating additional data where permanent meters are not feasible or affordable. Examples of suitable applications for error checking and data logging include:

- Production workshop performance
- Individual motors for fans and pumps
- Individual air compressors

Mobile water-flow meter

Ultrasonic clamp-on flow meters can be used for one-off measurement and temporary logging of water use to assess steady flow rates, such as in rinsing and batch filling of dye vessels.

Scope of Application

Although accuracy constraints need to be considered, mobile flow meters can be used throughout the water system, provided access is available to the relevant pipe.

Comparison

Figure 6: Comparison of portable meters

	Price (RMB/unit)	Accuracy +/- %	Installation and Maintenance	Life Span
Clamp-on	1,000 – 3,000[4]	5.0	Very easy	5 – 10 years
Mobile flow meter	5,000 – 20,000	5.0	Very easy	10 years

DATA COMMUNICATIONS AND LOGGING

No matter what meter types a factory uses, data from the meter must be communicated to a central location to be stored, analyzed, and used. A data communication network generally consists of a collection step where data is gathered from meter sensors at a given interval, and a consolidation step where data is processed and fed to a central location or server where it is further analyzed into regular reports for factory management to review. The most rudimentary metering data communications systems will rely on manual entry and transport of data- with factory workers walking to each meter and manually recording meter logs by hand onto paper or into a hand-held electronic logging device. Any manual system where data collection is not automated will suffer from inconsistent reporting intervals and error, which will make the system more labor-intensive and unreliable. An Automated data communication system can use wired or wireless technologies to relay meter data to a central server; and in many cases can be set up over an existing infrastructure such as telephone lines, power lines, wireless radio frequency, a computer local area network (LAN), or computer wireless network (Wi-Fi). These automated network options have different connectivity and cost profiles, and only some will allow continuous or real time factory metering (more on setting up a network, reporting intervals and networking options can be found on pages 16-17 of this report).

In automated data communication networks, the first step of data collection requires a probe either within a modern smart meter, or attached to a mechanical meter, that can transform the meter's mechanical tracking of flow to a uniform electronic signal or pulse.[5] This signal or pulse can then be sent at a programmed pulse rate to a data logger. Calibrating the proper data pulse from data collectors or smart meters requires an understanding of the expected flow rate at the meter, as improper pulse calibration can saturate data loggers and result in data loss.[6] Data loggers process and store data from a large group of individual meters, and can be set up to communicate with either on-site or off-site storage servers and computers via telephone or computer network cables. Data loggers can send information to a central server continuously for real-time data viewing and analysis, or can be set up to send information at an interval (e.g. at the end of a day or week). Network configuration will vary depending on the needs of the factory management as well as the technology used and its limitations.

ADDITIONAL TECHNICAL CONSIDERATIONS FOR DEVELOPING A METERING STRATEGY

The following technical issues are important to consider in the development of a metering strategy:

- **Coverage.** Meters must be installed in the most effective locations on-site.
- **Metering accuracy.** The selected metering technologies must operate at a sufficient level of accuracy to allow consumption and costs to be properly understood.
- **Reporting interval.** Metering technologies must report data regularly enough to provide sufficient insight into energy and water performance and costs.
- **Networking.** Data from individual meters must be collected in a centralized server for analysis.
- **Equipment pricing.** The costs and benefits of more sophisticated, accurate, and expensive metering systems must be understood.

METERING COVERAGE

Metering coverage reflects the location of meters and the number required. Coverage can be defined in terms of tiers or levels. NRDC's Clean by Design/Responsible Sourcing Initiative (RSI) developed a four-tier classification system for dye mills, summarized in the table below.

Figure 7: Overview of NRDC metering tiers

Coverage	Expected accomplishment	Extent of analysis
Tier 1	Main supplies are metered.	Factory
Tier 2A	Some but not all workshops are equipped with submeters.	Factory and workshop
Tier 2B	All workshops are equipped with submeters.	
Tier 3	Major energy-consuming machines are fully metered for monitoring and targeting, along with meters at the workshop level.	Factory, workshop, and equipment

Mills that do not have an effective energy management system in place will typically meter to Tier 1 or 2A. NRDC recommends Tier 2B as the first target for building a metering system for dyeing mills with existing Tier 1 and Tier 2A coverage. This will ensure that data from all major energy-consuming workshop locations are separately measured and analyzed. Metering can be extended to Tier 3 as energy management programs become more mature, as easy opportunities to improve efficiency are implemented, and as the cost and complexity of energy efficiency measures increase.

As data quality becomes more of a concern, smart meters, which enable automatic data capture and communication at regular intervals, will become preferred to manual capture of metered data. For facilities with limited existing metering infrastructure, building in remotely connectable smart meters from the outset instead of basic ammeters or kWh meters will reduce the cost of subsequent upgrading.

The Chinese National Standard GB17167-2006 outlines the general requirements for coverage of metering. Metering at the workshop level, or second tier, is mandated in the Standard, which defines thresholds of resource consumption (of energy, steam, water, etc.) and then dictates the percentage of workshop operations that must be covered by metering if these thresholds are exceeded. Most Chinese mill workshops will exceed these thresholds, except in the case of LPG or natural gas, the use of which is typically confined to the singeing process and the canteen.

Figure 8: Chinese National Standard GB17167-2006, workshop-level coverage

Resource	Workshop threshold for metering	Minimum coverage (%)
Electricity	10 kW	100
Steam	5,000 GJ/year	80
Water	5,000 ton/year	95
Coal	100 ton/year	100
Heavy oil/diesel	80 ton/year	100
LPG	40 ton/year	100
Natural gas	10,000 m^3/hr	100

Tier 3 metering is also covered in the Standard. Individual equipment with resource consumption ratings above designated thresholds must be metered. The minimum percentage of metering coverage for these "significant" units is shown below.

Figure 9: Chinese National Standard GB17167-2006, equipment-level coverage

Resource	Equipment unit consumption threshold	Minimum coverage (%)
Electricity	100 kW	95
Steam	7 MW	70
Water	1 ton/hr	80
Coal	1 ton/hr	90
Heavy oil/diesel	1 ton/hr	90
LPG	0.5 ton/hr	90
Natural gas	100 m^3/hr	90

METERING ACCURACY

More accurate meters tend to be more expensive but can be justified when the data collected result in increased cost savings. Figure 11 summarizes some of the benefits of improved accuracy at each of the three metering tiers.

Figure 10: Opportunities from improved accuracy

Tier 1	More accurate production benchmarking of resource consumption (e.g., MJ consumed per ton of fabric produced, tons of water consumed per ton of fabric produced)
	Opportunity to verify accuracy of utility energy and water bills and identify overcharging by the utility
Tier 2	Opportunity to benchmark workshops with similar process types against each other
	Opportunity to engage staff and measure against incremental performance goals
Tier 3	Most accurate production benchmarking
	Improved ability to detect abnormal performance
	Sensitivity to small improvements, such as leak reduction programs

For guidance purposes, the Chinese Government Standard GB 17167-2006 recommends accuracy levels and types of instrumentation for electricity metering, based upon total annual electricity consumption.

Figure 11: Chinese Government Standard GB 17167-2006 regarding accuracy and recommended metering instrumentation

Annual electricity consumption	Accuracy requirement (+/– %)	Recommended instrument
More than 60,000,000 kWh, or transformers larger than 10,000 kVA	0.5S	Smart meter only
More than 12,000,000 kWh, or transformers larger than 2,000 kVA	0.5	Smart meter only
More than 1,200,000 kWh, or transformers larger than 315 kVA	1.0	Smart meter only
Transformers smaller than 315 kVA	2.0	Smart/mechanical smart meter
Single phase	2.0	Smart/mechanical smart meter

RESET also has compiled suggested accuracy levels indicating a practical level of accuracy that could guide Chinese dye mills in the development of metering strategies. These are based on RESET market observations and experience with Chinese dye mill clients and products available in the Chinese market.

Figure 12: Suggested accuracy levels for non-electricity metering based on RESET analysis in the Chinese market

	Recommended accuracy (+/– %)			
	Steam	Compressed air	Water (full pipe)	Portable meters
Tier 1 – Whole factory	2.0	2.0	1.0	<5
Tier 2A/B – Plants/ workshops	2.0	2.0	2.0	
Tier 3 – Equipment	2.0	2.0	2.0	

REPORTING INTERVAL

Balancing the frequency at which meters report data is an important component of generating a relevant, reliable energy and water performance dataset.

Undercollecting, for example collecting data on a monthly basis, will not give energy managers sufficient insight into how efficiently a system is responding to different load conditions throughout the day, or to variations in production. On the other hand, excessive reporting can present energy managers with data overload, particularly if software or other data processing tools are not effectively utilized.

The following figure suggests appropriate data collection intervals for different data types, metering technologies, and tiers of metering. This information is based on RESET client work with Chinese dye mills.

Figure 13: Recommended data collection intervals for different meters and tiers

Meter and data type	Tier and interval time		
Smart electricity meter	**Tier 1**	**Tier 2**	**Tier 3[7]**
kW	3-5 min	3-5 min	1 min
Power factor	1 hr	1 hr	1 hr
kWh	Daily	Daily	Daily
Steam meter			
Cumulative volume	Daily	Daily	Daily
Flow rate	5-10 min	5-10 min	1 min
Temperature	1 hr	1 hr	1 hr
Pressure	5-10 min	5-10 min	1 min
Compressed-air meter			
Cumulative volume	Daily	Daily	Daily
Flow rate	5-10 min	5-10 min	1 min
Pressure	5-10 min	5-10 min	1 min
Water meter			
Cumulative volume	Daily	Daily	Daily
Flow rate	5-10 min	5-10 min	1 min

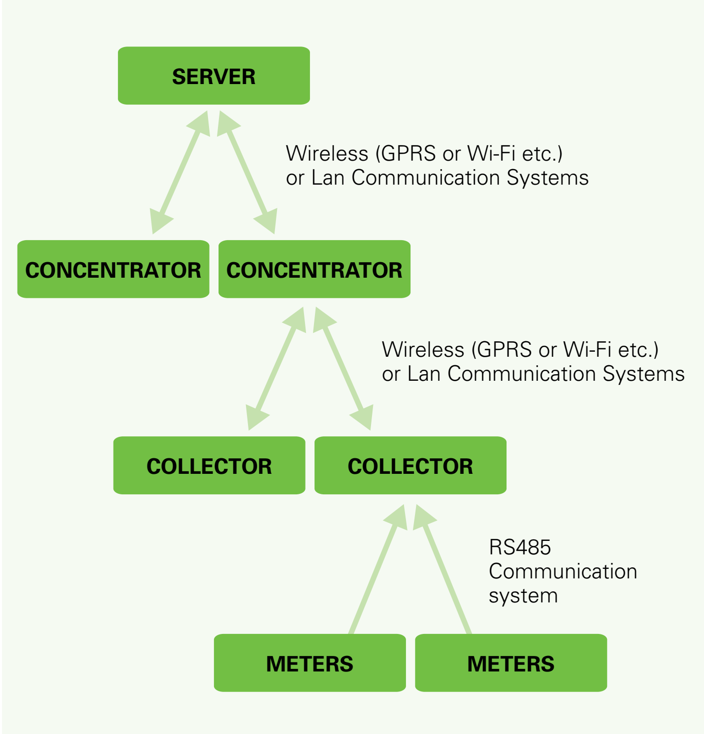
NETWORKING

For Tier 1 and 2A metering, manually captured data can be sufficient to get a basic overview of energy performance, to achieve simple production benchmarking, and to support billing activities, with utilities consumption and production data tracked monthly.

As metering systems mature, and particularly with larger sites such as dye mills, effective manual data collection, processing, and analysis become both too time-consuming and too difficult to consistently manage. A system that networks meters into a central server where information can be collected and analyzed by software tools becomes increasingly valuable.

An overview of a typical network structure is provided in the schematic below.

Figure 14: Diagram outlining levels of data collection and consolidation between meter and server



As Figure 14 shows, most networked metering systems will follow a hierarchy that efficiently moves and consolidates metering data, packaging it into a form that can be processed and analyzed by software on a central server.

In between the meter and the server, two layers of consolidation can often be found.

- **Collectors** receive data directly from meters and relay this data in a form that can be accepted by concentrators or servers farther up the network hierarchy. Collectors are located close to meters, ensuring that meters can relay information via low-cost data transmission technologies like pulse probes using RS485, a widely used industrial automation technology.
- **Concentrators** or data loggers are used to consolidate data from collectors and utilize more expensive data transmission technologies with greater range, such as wireless systems like Wi-Fi or GPRS/GSM, or wired systems like telephone lines, power lines or a computer local area network (LAN). Concentrators have additional functions as well, such as the ability to pass instructions back to collectors or temporarily store data while awaiting a server request.

Structuring a network, balancing the different capabilities of meters, collectors, and concentrators, and choosing appropriate data transmission technologies will depend upon the physical distance the data need to travel, the volume and complexity of data desired for processing at the central server, and the mill's budget.

Figure 15: Methods for Meter Network Communication

	Cost	Data Continuity	Speed	Interruption
Power Line	High when new, usually existing	Continuous	Low	Data loss can occur
Phone Line/ Telephone Modem	Low when new, usually existing.	Only on scheduled call-in		Secure. Can use off-peak times when sharing line
LAN	Low when new, increasingly existing.	Continuous	Fast	Low, increased data sharing opportunities. most diverse protocol options
Wireless	High when new, typically new system	Continuous	Fast	Distance limitations
GPRS/GSM	Moderate, uses existing cellular network	Rapid data bundles	Fast	

EQUIPMENT PRICING

Pricing is a critical issue for most mill operators, who are keen to minimize capital expenditure. Generally speaking, the cost of metering technology will increase with sophistication and accuracy.

Meter pricing for industrial clients in the Chinese market is subject to considerable variation both from place to place and over time. Most metering contracts are negotiated as bundled packages, with pricing impacted by issues such as the size of the project, the presence of other equipment purchases, and the mill's relationship with the equipment provider. Pricing also varies among brands of meter. Moreover, it has been consistently observed that generic product information available from equipment manufacturers often overstates the price paid by dye mills for meters in the marketplace. The pricing offered in the following table is therefore designed as an *indicative guide for reference only*. This pricing has been drawn from Clean By Design mills or by other RESET projects.

Figure 16: Indicative pricing for metering technology for Chinese dye mills

	Meter type	Accuracy (+/– %)	Indicative price (median)
Electricity	Smart (with 3 CTs)	0.5	3,000 RMB
	Mechanical (with 3 CTs)	2.0	900 RMB
Steam	V-cone	2.0	15,000 RMB
	Orifice	2.0	5,000 RMB
Water	Electromagnetic	2.0 (not full)	16,000 RMB
	Ultrasonic	<10 (not full)	6,000 RMB
	Smart	<5	1,000 RMB
Compressed Air	Vortex	2.0	19,000 RMB
	Orifice	3.0	9,000 RMB
Portable	Clamp-on	<5.0	3,000 RMB
	Ultrasonic flow	<5.0	5,000 RMB
Network	LAN		
	Wi-Fi		200 RMB/spot
	GPRS		1,000 RMB/spot
Software + hardware package			20,000 RMB/spot

METERING STRATEGY AND PROCUREMENT

This Guide recommends a series of simple steps for mills to consider when developing or upgrading their energy and water metering system and hardware. Where possible, metering should be considered as a strategic component of a broader energy/water management program.

METERING GOALS

Clear goals for the metering program should be developed. These goals will guide the design of the system, the selection of the appropriate types of meters, and the data recording strategy. One way to develop such goals is to decide what questions need to be answered by the data. For example:

- How much water/energy does my plant use every day/month?

  Answer with Tier 1 metering, recorded daily.
- Does water/energy use vary greatly, depending on the type of fabric my plant is dyeing?

  Answer with Tier 1 metering, read as frequently as fabric types change.
- How much electricity is my mill using in the office and dormitories versus the factory floor?

  Answer with Tier 2A metering at each location.
- How much energy is the mill using for dyeing machines versus finishing?

  Answer with Tier 2B metering for separate workshops, recorded at least daily.
- Are similar pieces of equipment or processes running in different workshops performing in similar ways?

  Answer with Tier 2B metering for separate workshops, recorded at least daily.
- Is new equipment operating according to specifications?

  Answer with Tier 3 metering for major pieces of equipment, with automated continuous data recording.
- Are there leaks and malfunctions in major pieces of equipment causing spikes in water and energy consumption?

  Answer with Tier 3 metering for major pieces of equipment, recorded at least daily.
- Where are leaks and malfunctions occurring, and when?

  Answer with Tier 3 metering for major pieces of equipment, with automated continuous data recording.

These are only some examples of the questions that can be answered using different levels of metering.

METERING STRATEGY AND DESIGN

Once the goals and objectives of the metering system have been identified, it will become clear where additional meter investments are needed to track resource use and to establish a baseline against which improvements can be measured. Projected savings from the water/energy efficiency projects can be used to offset initial capital outlay for the meters themselves.

Metering strategy and design can be carried out internally or via a third-party energy/water management specialist, depending upon internal skill sets and the complexity of the program envisaged.

PROCUREMENT

Meters are widely available in most markets, and mills will be able to secure quotes from established equipment suppliers for hardware and installation costs. Installation can usually be carried out by a local contractor.

With a metering strategy and design in place, mills should ideally prepare a detailed tender including technical specifications and drawings for hardware, communications, storage, processing, and reporting.

Mills should also ensure that they validate the capability of potential suppliers and seek quotes, method statements, and technical submissions as part of each proposal.

EXAMPLE 1: TEXTILE MILL SEEKING TO IMPLEMENT ENERGY MANAGEMENT PROGRAM FOCUSED ON NRDC TEN BEST PRACTICES

This section presents a hypothetical metering design response to an energy management opportunity in a medium-size mill. It is based on an example from the NRDC Clean by Design portfolio and is in many ways typical of the opportunities open to textile mills in China. It is designed to illustrate how a typical metering program could be developed at a mill with a basic existing metering structure and limited management of energy and water costs.

In this example, the mill seeks to understand existing patterns of energy and water use and then use this information to identify efficiency opportunities on-site.

ABOUT THE MILL

A denim fabric mill has several physically separated buildings containing corporate headquarters, dyeing, rotary printing, and a steam and hot-oil boiler plant. The annual output of the denim dyeing section is approximately 30,000,000 yards. At the start of the project, the mill had a metering system at the Tier 2A level—that is, partial metering at the workshop level. The mill does not have an on-site wastewater treatment plant but uses a collective municipal facility.

MAPPING ENERGY DEMAND AND EFFICIENCY OPPORTUNITIES

In this example, a third-party water and energy audit was conducted to provide good insight into patterns of energy and water use and measures for improved efficiency. Although submetering was not in place at the mill during the time of the assessment, third-party assessments can construct a model of facility energy and water use by cross-referencing overall consumption data with a bottom-up demand analysis developed from estimating the operating hours of key machinery.

The assessment provided insight into the overall energy and water use at the mill and yielded a list of strong savings opportunities.

Figure 17: Baseline energy and water consumption of the mill

Electricity (kWh)	Tap water (t)	Wastewater treatment (t)	Coal (t)	LPG (kg)
13,000,000	1,000,000	800,000	40,000	200,000

Figure 18: Energy and water efficiency assessment recommended measures

Savings area	Electricity saving (kWh)	Steam saving (t)	Cost savings per year (RMB)	Capital investment excluding meters (RMB)	Payback period excluding metering costs (yr)[8]
Wastewater heat recovery		8,500	1,270,000	220,000	0.2
Boiler replacement		12,000	1,800,000	2,000,000	1.2
Drying roller insulation		490	70,000	100,000	1.5
Compressed-air traps	60,000		40,000	6,000	0.2
Cooling system variable-speed drives	50,000		30,000	55,000	1.9
Other	200,000	3,000	590,000	319,000	0.6
Total	**310,000**	**23,990**	**3,800,000**	**2,700,000**	0.8

DEVELOPING AN ENERGY MANAGEMENT ACTION PLAN

Based upon the results of the evaluation of efficiency opportunities, the facility developed goals for efficiency improvements. These goals included:

- Resource reduction per unit of production at the facility level.
- Resource reductions within specific resource-intensive processes or locations.

With these goals in mind, the mill developed an action plan to implement the full set of measures recommended by the audit, with the goal of achieving the projected energy savings outlined in the assessment. The action plan included a strategy for monitoring associated savings based on metering.

METERING STRATEGY AND DESIGN

Given the breadth of energy saving opportunities, additional metering of major workshops and all major energy- and water-using equipment would allow the mill to:

- Establish a baseline for energy and water use before energy efficiency projects were developed so that savings and ROI could be calculated.
- Benchmark energy use against production, enabling the mill to report to brand customers about their efficiency.
- Provide detailed, ongoing performance reporting to help the mill develop new savings opportunities.
- Monitor the performance of equipment on a daily or weekly basis as appropriate.
- Compare performance among workshops with similar types of equipment.
- Evaluate how normal changes in production (type of fabric, color, etc.) affect water and energy use.

A metering design upgrading from Tier 2A to Tier 3 was developed. The projected capital cost of the metering upgrade was projected at RMB 244,200 for hardware, with an additional RMB 200,000 for analytical software.

Figure 19 shows a summary of the metering upgrade:

Figure 19: Summary of projected meters and networking technology numbers and costs

Meter type	Existing quantity (Tier 2A)	Total quantity (Tier 3)	Investment (RMB)
Electricity	2	17	41,400
Water	4	25	77,000
Steam	1	16	85,000
Networking hardware			40,800
Software			200,000
Total (hardware+software)			**444,200**

A combination of metering technologies was used to provide a suitable level of accuracy at a manageable cost:

- **Electricity:** Smart meters were selected over mechanical meters throughout the mill, given the importance of logging and networking results on a frequent basis.
- **Water:** Electromagnetic meters were selected for major pipes because high flow rates and water costs justified the greater expenditure for a more accurate meter. Mechanical meters were suggested to reduce the costs of Tier 3–level metering, where volume was lower and accuracy less important.
- **Steam:** Orifice meters were suggested because accuracy requirements did not necessitate a more expensive metering option. Costs of individual orifice meters would be higher if they were used for Tier 1 and 2 metering, because the pipe size is larger and therefore larger meters are required.
- **Networking:** A simple hierarchy of collectors and concentrators was developed linking the meters to a central server. Close-proximity collectors allowed connection to meters using a low-cost RS485 Local Area Network (LAN). Collectors were linked to concentrators with LAN where possible or Wi-Fi where distance or accessibility precluded effective LAN connection. Concentrators were linked to the server using LAN.

Details on the metering configurations are described further in the figures following.

Figure 20: Projected electrical metering requirements by location

Electrical Metering System						
Location		**Accuracy (+/– %)**	**Type**	**Quantity**	**Unit price (RMB)**	**Total**
Tier 1	Factory	0.5S	Smart	1	3,000	3,000
Tier 2	Dyeing and finishing plant	1.0	Smart	1	1,600	1,600
	Printing	1.0	Smart	1	1,600	1,600
	Boiler plant	1.0	Smart	1	1,600	1,600
	Compressor room	1.0	Smart	1	1,600	1,600
Tier 3	Dyeing	1.0	Smart	9	1,600	14,400
	Setting	1.0	Smart	2	1,600	3,200
	Scouring	1.0	Smart	1	1,600	1,600
	Mercerizing	1.0	Smart	2	1,600	3,200
	Boilers	1.0	Smart	3	1,600	4,800
	Compressors	1.0	Smart	3	1,600	4,800
Total				**25**		**41,400**

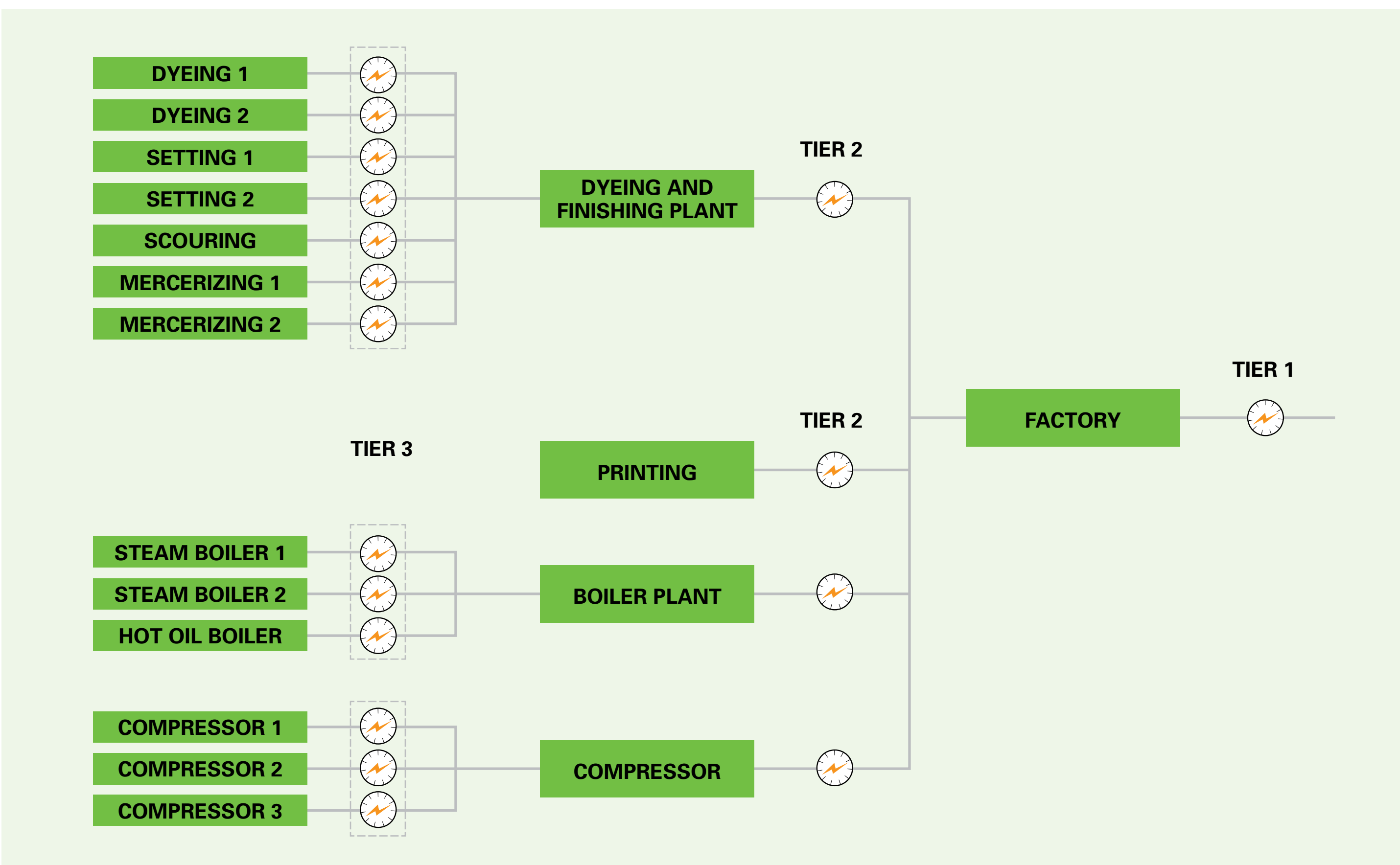


Figure 21: Projected water metering requirements by location						
Water Metering System						
	Location	**Accuracy (+/– %)**	**Type**	**Quantity**	**Price (RMB)**	**Total**
Tier 1	Factory	1.0	Electromagnetic	1	16,000	16,000
Tier 2	Dyeing and finishing plant	1.0	Electromagnetic	1	16,000	16,000
	Printing	1.0	Electromagnetic	1	16,000	16,000
	Boiler plant	1.0	Electromagnetic	1	16,000	16,000
Tier 3	Dyeing	2.0	Mechanical	9	1,000	9,000
	Mercerizing	2.0	Mechanical	2	1,000	2,000
	Boilers	2.0	Mechanical	2	1,000	2,000
Total				**17**		**77,000**

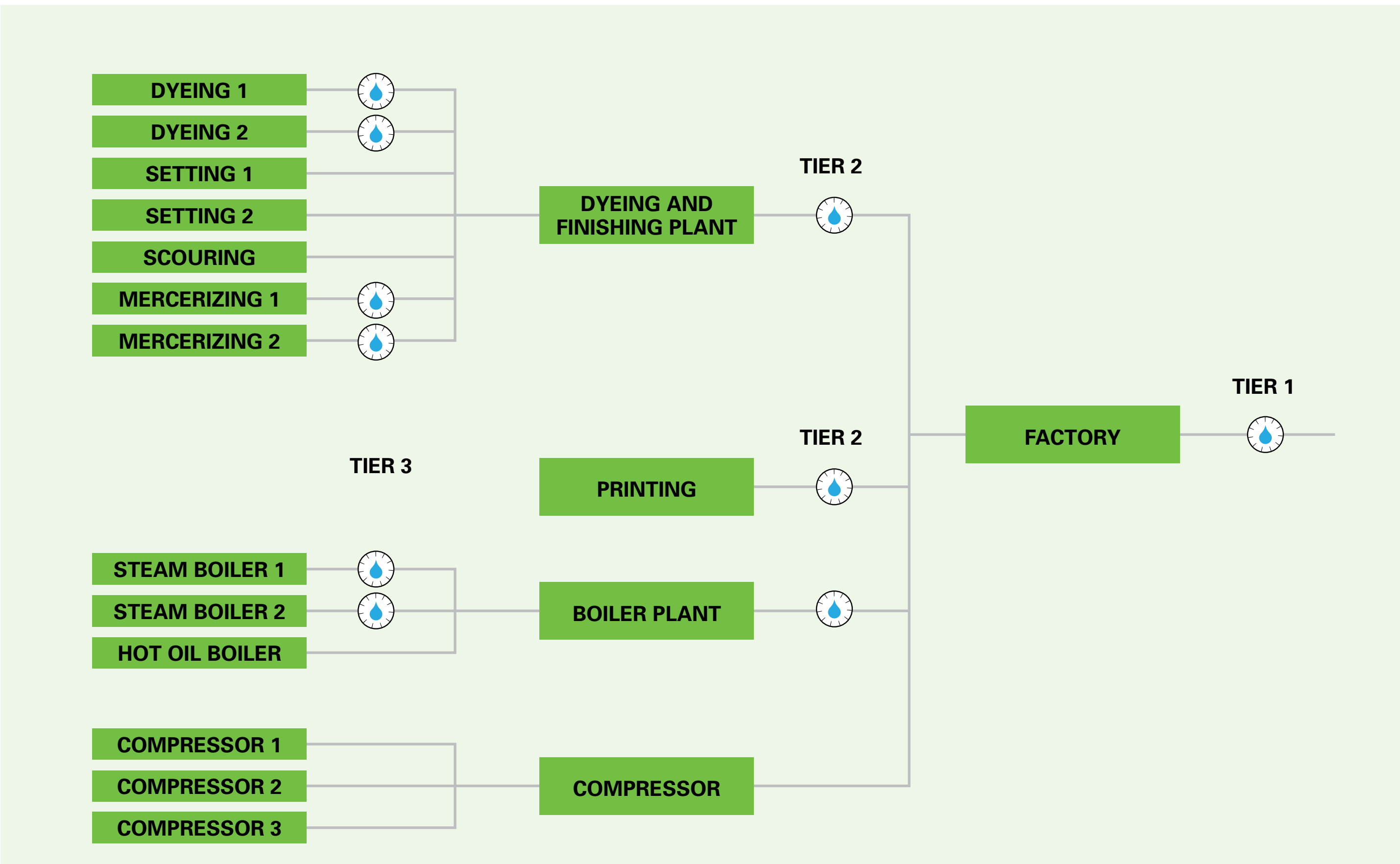


Figure 22: Projected steam metering requirements by location

Steam Metering System						
	Location	Accuracy (+/– %))	Type	Quantity	Price (RMB)	Total
Tier 1	Boiler room	2.0	Orifice	1	8,000	8,000
Tier 2	Dyeing and finishing plant	2.0	Orifice	1	6,000	6,000
	Printing	2.0	Orifice	1	6,000	6,000
Tier 3	Dyeing	2.0	Orifice	9	5,000	45,000
	Mercerizing	2.0	Orifice	2	5,000	10,000
	Boilers	2.0	Orifice	2	5,000	10,000
Total				**16**		**85,000**

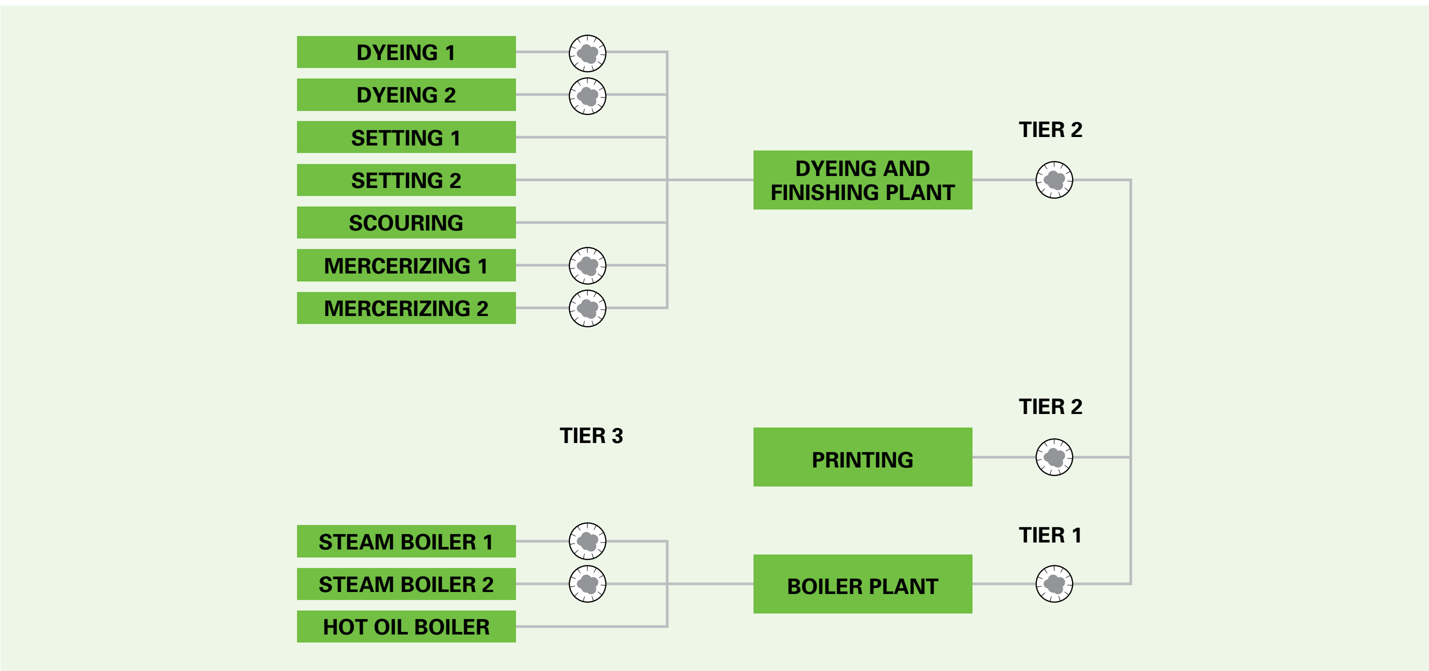


Figure 23: Projected networking requirements

Networking System			
	Quantity	Unit price (RMB)	Total cost (RMB)
Collector	9	1,200	10,800
Concentrator	3	2,800	8,400
Wi-Fi	8	200	1,600
Server	1	20,000	20,000
Total			**40,800**

EXAMPLE 2: TEXTILE MILL SEEKING TO DEVELOP A SIMPLE MONITORING SYSTEM TO BETTER UNDERSTAND ENERGY COSTS

ABOUT THE MILL

The hypothetical mill is a medium-size operation that includes a dyeing plant and finishing plant along with an additional boiler plant and a compressor plant. The mill management is seeking more information on the breakdown of energy costs within the facility to provide a basis for developing an energy management program and potentially also for reporting data to its customers. The mill operators wish to keep the capital costs involved to a minimum at this stage.

MAPPING ENERGY DEMAND AND EFFICIENCY OPPORTUNITIES

At this stage mill management has not opted for an energy efficiency assessment. It first desires to better understand existing energy use patterns and seeks opportunities for easy energy efficiency savings driven by its own engineering team.

DEVELOPING AN ENERGY MANAGEMENT ACTION PLAN

At this stage an action plan is not envisioned until more information regarding existing patterns of energy use have been determined.

METERING STRATEGY AND DESIGN

A simple design expanding from Tier 1 to Tier 2A was chosen in order to minimize capital expenditure while providing an additional layer of insight. Due to the small number of meters involved and the fact that high levels of accuracy are not required at this stage because no return on investment is being calculated, low-cost mechanical meters were preferred.

Figure 24: Metering structure

	Existing quantity (Tier 1)	Additional quantity (Tier 2A)	Meter type	Unit Price (RMB)	Total (RMB)
Water	1	3	Mechanical	1,000	3,000
Electricity	1	4	Mechanical	600	2,400
Steam	0	1	Orifice	5,000	5,000
Package Price					**10,400**

Proposed locations for the eight additional Tier 2 meters are outlined in the following schematics.

Figure 25: Projected locations of electricity meters

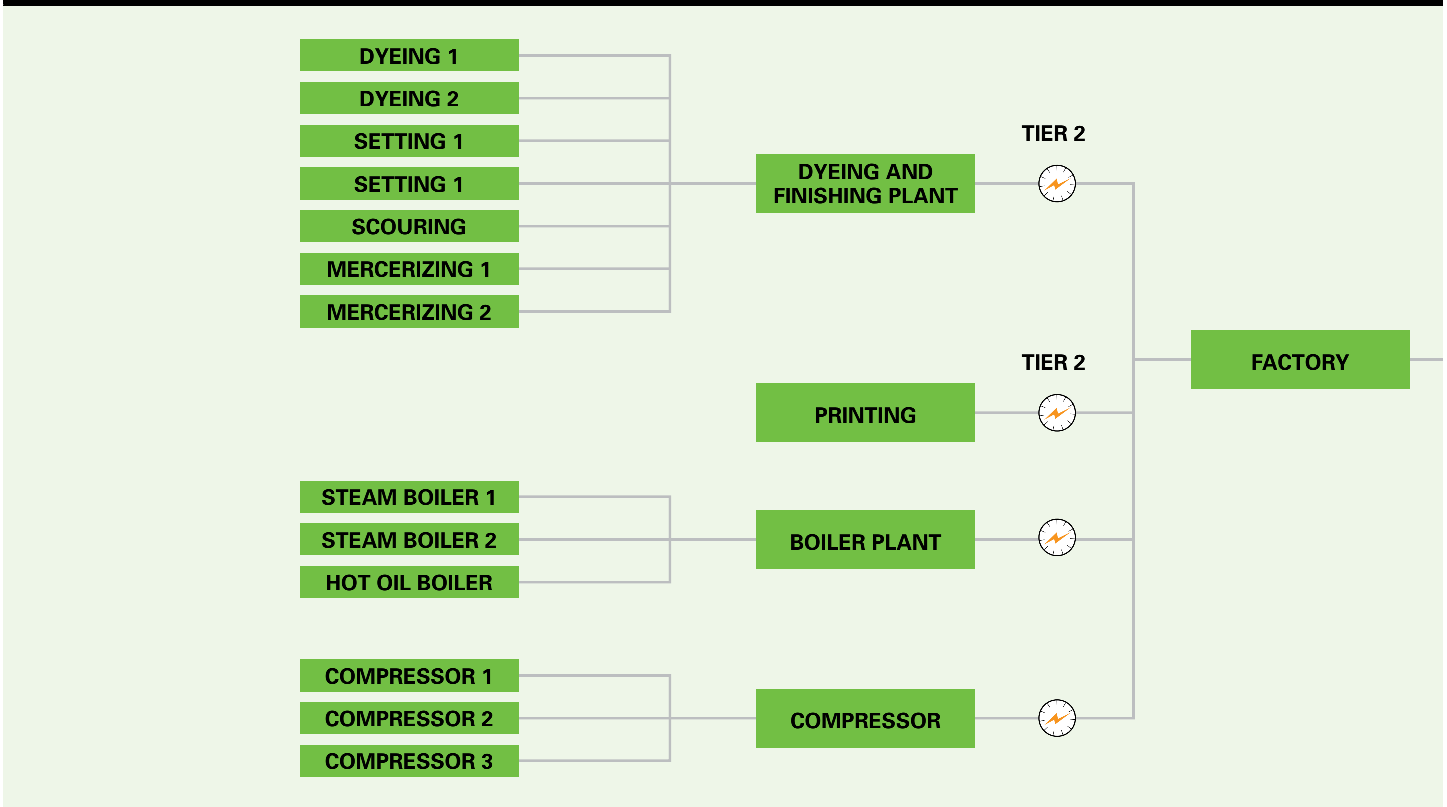


Figure 26: Projected location of steam meter

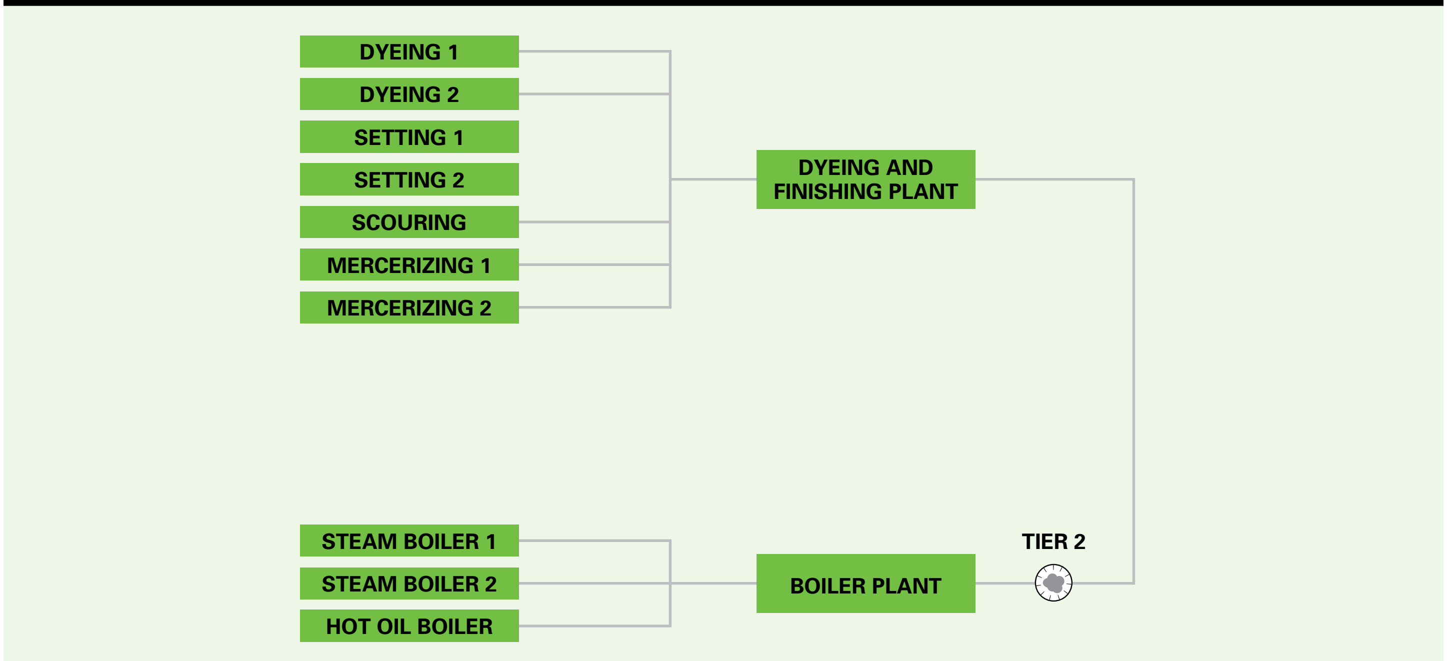
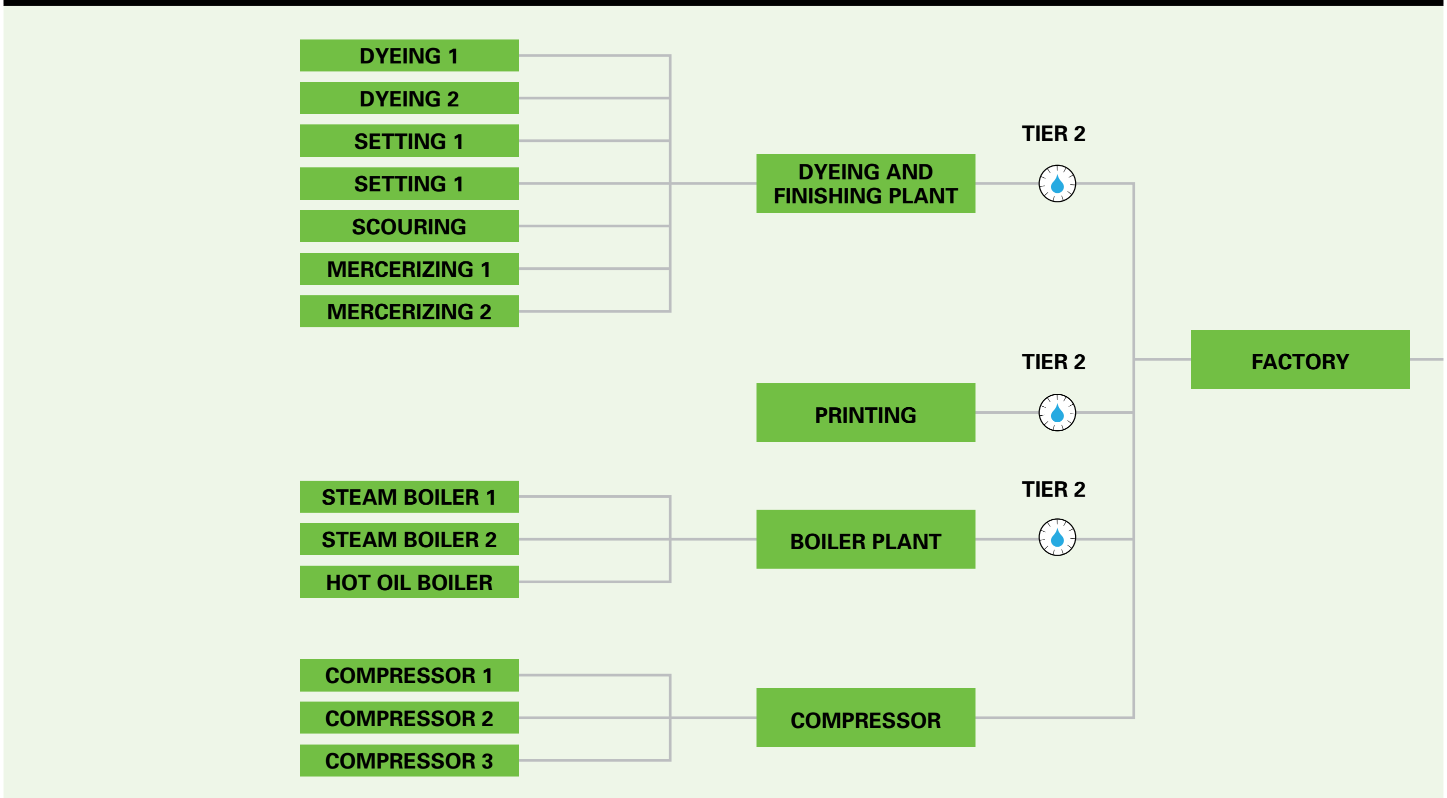


Figure 27: Projected locations of water meters



CONCLUSIONS

Metering offers critical information on the use patterns of water and energy within factories over time and over a wide variety of production conditions. Armed with this information, factory managers can not only more effectively manage day-to-day operations but can also identify the best places to focus their efforts to improve energy and water efficiency in the longer term. Factories that invest in metering systems will have clear, reliable data to provide to the growing number of customers who demand environmental performance information as part of the business relationship. Metering allows factories to pinpoint ways to save resources and money, improve the quality and timeliness of production, and minimize their water and energy footprint—making metering a win-win for business and the environment.

Endnotes

1 The bar is a unit of pressure, equivalent to atmospheric pressure or 100,000 pascals.

2 Price is for meters measuring water under 80°C.

3 Includes basic-pulse type communication provisions.

4 Additional costs will be incurred if more sophisticated data-logging capability is required.

5 Hauber-Davidson, Gunter; Idris, Elsa. "Smart Water Metering," *Water* 2006, 33, p.40.

6 U.S. Department of Energy, Metering Best Practices: A Guide to Achieving Utility Resource Efficiency, Federal Energy Management Program. August 2011, p.106-107.

7 To more effectively monitor abnormal performance and leaks, Tier 3 meters should collect at 1-minute intervals.

8 Rounded up.

NRDC
THE EARTH'S BEST DEFENSE

Natural Resources Defense Council
40 West 20th Street
New York, NY 10011
212 727-2700
Fax 212 727-1773

Beijing

Chicago

Los Angeles

Bozeman

San Francisco

Washington

www.nrdc.org

www.nrdc.org/policy
www.facebook.com/nrdc.org
www.twitter.com/nrdc

Printed on recycled paper