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PEZA GTZ Cooperation Eco Industrial Development (EID) Project

Energy Survey & Audit Guidelines

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1 INTRODUCTION

1.1 SURVEYS AND AUDITS

At the beginning of an energy management initiative, it is important to determine the current position (base case). Once this has been established it is then possible to set goals and priorities for future improvement.

To determine the current position it is important to be able to answer questions such as:

- What types of energy are used?
- How much is being used?
- How much does it cost?
- Where is the energy being used?
- How efficiently is energy being converted, distributed and used?
- What are the potential savings?
- How can they be achieved?
- How much will it cost to achieve the savings?
- What are the priority areas?

All the questions posed are important and can be answered by conducting an energy survey.

Definition
Energy audit: a study to determine the quantity and cost of each form of energy to a:

- Building …
- Process/manufacturing unit …
- Piece of equipment …
- Site …

… over a given period, usually a year.

For example:

Utility	Energy Consumption		Cost		CO_2 Emissions
	Consumption pa	%	Pesos pa	%	Tonnes pa
Electricity	43,048,766	100	196,302,000	100	4,390.9
Total energy	**43,048,766**	**100**	**196,302,000**	**100**	**4,390.9**

OR

Utility	Energy Consumption		Cost		CO_2 emissions (tonnes)
	kWh/year	%	P/year	%	
Electricity	22,202,658	37.1	725,000	58.5	9,547
Gas	37,591,533	62.9	515,000	41.5	7,142
Total Energy	**59,794,191**	**100**	**1,240,000**	**100**	**16,689**

Energy survey: a technical investigation of the control and flow of energy in a:

- Building …
- Process/manufacturing unit …
- Piece of equipment …
- Site …

… with the aim of identifying cost-effective energy saving measures.

Energy surveys can be conducted on entire sites, individual manufacturing units, utility systems or specific items of equipment.

Usually surveys include an examination of:

- Management systems: how information is obtained, analysed, and used. Management and people issues.
- Energy conversion: where energy is converted from one form to another, eg heaters, boilers, furnaces, refrigeration units, compressors, turbines, etc.
- Energy distribution: where energy is distributed, eg electricity, gas, steam, air, water, hot oil systems.
- Energy end use: where energy is used in plant, equipment and buildings.

An energy survey will usually give a management summary and divide recommendations into three main categories:

- Energy Management
- No-cost (good housekeeping)& low-cost measures
- Medium/High-cost measures

Examples of these three categories are given below:

Energy Management Opportunities

No	Description	Cost	Savings	Savings	Elect	Payback	CO_2 pa
		Pesos	Pesos	kWh pa	%	Years	tonnes
1	Energy Management	500,000	9,815,118	2,152,438	100	Immediate	219.5
	• Policy. Good commitment to environment improvement written and displayed with managers signature which is a good positive step but could do with separate energy policy.						
	• Information systems. Good but could be better no M&T however could be possible through existing BMS and start with CA chillers and one another pilot area. Try to undertake analysis like CUSUM and targets for improvement						
	• Investment. Could be better. Although investments are identified and supported with analysis, all Capex measures need to be agreed at corporate level with little discretion at local level						

No/low Cost Saving Opportunities

2	Compressed air leakage	50,000	2,944,535	645,731	100	Immediate	65.8
3	Add insulation to ovens	100,000	262,656	56,600	100	0.5	5.7

Medium/High Cost Saving Opportunities

4	M&T System	445,000	616,267	135,146	100	0.6	13.7
5	Vent system improvement	1,751,000	875,520	192,000	100	2.0	19.6
6	Commission CWCP VSD	100,000	1,020,528	223,800	100	0.4	22.7
7	Compressed air intake improvement	450,000	294,453	64,573	100	1.5	30
8	AHU VSD and Air Leakage Imp.	500,000	1,413,377	309,951	100	0.3	31.5
9	Comp. Air local isolators	300,000	588,907	129,146	100	0.5	13.1
	Total	**4,196,000**	**17,831,361**	**3,909,385**		**0.6**	**421.6**

1.2 FINDING SAVINGS

Survey Topic Guides
The topic guides in this section provide a framework for your survey. They are structured as follows.

Each deals with a generic industrial process (boilers, for example) or a site service such as lighting or compressed air.

Each starts with a list of things to look for. These are things which are often amiss, where common sense and local knowledge will normally be sufficient to dictate an appropriate remedy, and where it should be quick and cheap – or even free – to put the problem right. This may be as far as you need to go.

For those who want to go further, each topic guide has a selection of tips and tricks.

Next comes a list of potential opportunities. These only apply if you are prepared to contemplate moderate to high cost remedial works.

2. ENERGY MANAGEMENT - ORGANISING
Organising Energy Management

Success factors to look for

- An enthusiastic champion
- A motivated and energy-aware workforce
- A culture of engagement and c o-operation
- Support from senior management
- True accountability for energy costs
- Corporate willingness to rectify problems with existing energy-related services
- Training for those whose day-to-day work impinges on energy efficiency
- A team approach on the part of the relevant players
- Continuous feedback of results and achievements
- Opportunities created by external factors (eg supply capacity constraining growth)

Assessment and goal-setting
The energy management matrix is divided into six key organisational aspects of energy management :

- Policy
- Organising
- Training
- Performance measurement
- Communicating
- Investment

To obtain an indication of the current state of the organisational aspects on your site complete the matrix by putting one cross in each column. The box you mark under each column should represent the current status on your site. Then join your crosses across the columns to produce your organisational profile. This will show your strengths and weaknesses. Weaknesses can undermine strengths so the ideal profile is one which is relatively flat. From that position it is important to advance on all aspects up the matrix.

Some companies find it useful to copy the matrix and get a group of managers to individually complete the matrix in a meeting and then compare findings. See below.

In the rest of this section each of the organisational aspects are covered briefly with pointers to further information.

Energy Management Matrix Assessment

Level	Energy Policy	Organising	Motivation	Information systems	Marketing	Investment
4	Energy policy, action plan and regular review have commitment of top management as part of an environmental strategy	Energy management fully integrated into management structure. Clear delegation of responsibility for energy consumption.	Formal and informal channels of communication regularly exploited by energy manager and energy staff at all levels.	Comprehensive system sets targets, monitors consumption, identifies faults, quantifies savings and provides budget tracking.	Marketing the value of energy efficiency and the performance of energy management both within the organisation and outside it.	Positive discrimination in favour of 'green' schemes with detailed investment appraisal of all new-build and refurbishment opportunities.
3	Formal energy policy, but no active commitment from top management.	Energy manager accountable to energy committee representing all users, chaired by a member of the managing board.	Energy committee used as main channel together with direct contact with major users.	M&T reports for individual premises based on sub-metering, but savings not reported effectively to users.	Programme of staff awareness and regular publicity campaigns.	Same payback criteria employed as for all other investment.
2	Un-adopted energy policy set by energy manager or senior departmental manager.	Energy manager in post, reporting to ad-hoc committee, but line management and authority are unclear.	Contact with major users through ad-hoc committee chaired by senior departmental manager.	Monitoring and targeting reports based on supply meter data. Energy unit has ad-hoc involvement in budget setting.	Some ad-hoc staff awareness training.	Investment using short-term payback criteria only.
1	An unwritten set of guidelines	Energy management is the part-time responsibility of someone with limited authority or influence	Informal contacts between engineer and a few users.	Cost reporting based on invoice data. Engineer compiles reports for internal use within technical department.	Informal contacts used to promote energy efficiency.	Only low cost measures taken.
0	No explicit policy	No energy management or any formal delegation of responsibility for energy consumption	No contact with users.	No information system. No accounting for energy consumption.	No promotion of energy efficiency.	No investment in increasing energy efficiency in premises.

2.2 ENERGY MANAGEMENT – PEOPLE ASPECTS

Communication

Every employee can make a contribution to saving energy. Often, contractors should also be included. Two key aspects are required: awareness and motivation.

Raising awareness covers the knowledge and skills so that people see the potential for saving energy as an integral part of their daily work. Awareness is knowing what to do.

Motivation is more complex. It varies from person to person. Key factors include 'external' motivators, eg incentives, targets, competition to perform and 'internal' motivators related to personal outlook and values (eg concerns for the environment).

Good housekeeping campaigns need to be integrated into other energy management initiatives if momentum is to be maintained.

Training

On every site there are key people who can have a large influence on energy consumption because of their job function. These people need to be identified along with their training needs so that they receive appropriate training to be energy efficient. Individuals are usually saving energy or wasting it and there is rarely any neutral ground. In many industrial sites the Pareto principle rules: 20% of the workforce control 80% of the energy.

If energy efficiency investment measures are not supported by appropriate training then potential savings will not be fully realised because of poor operation, control and maintenance practices.

Investment in vocational training for key staff (eg boiler or plant operators) not only saves energy but also improves environmental performance and standards of health and safety. The specialised needs of the individual energy manager must not be overlooked.

A Framework for Training Needs

In a large operation, an integrated programme of training may be worth developing. This will need to address three categories of training need, and the matrix below shows what topics might typically be covered and at what level.

Case Histories

At a small injection-moulding plant, about P20,000 was spent on meters to make staff more aware of where and how energy was being used. They saved P210,000 in the first year.

A manufacturer of decorative tiles persuaded its suppliers to donate prizes for an energy awareness campaign.

Subject	**Audience**		
	Operators	**Engineers Managers**	**General Management**
Overview of energy efficiency	A	A	A
Energy billing		A	V
Performance Monitoring & targeting	A	V,T	T
Meter readings	V	T	
Energy considerations	A	V,T	A
Boiler operation	V	T	A
Steam systems	V	T	A
Pumps & fans	A	V,T	A
Electric motors and drives	A	V,T	A
Compressed air systems	V	T	A
Lighting	A	V,T	A
AHU & chilling	A	V,T	A

Key :

V = Vocational Material directed at improving skills, enabling trainees to do their jobs better. Likely to include some practical element.

T = Theoretical Material aimed at improving knowledge and understanding, enabling better analysis and decision making.

A = Awareness Brief coverage to help trainees understand people's objectives and activities, to put their own contribution in context, and to defuse potential conflicts.

2.3 ENERGY MANAGEMENT - MONITORING & TARGETING

Purpose

An energy survey can only ever be a snapshot. It is therefore best at detecting opportunities for permanent modifications to plant, equipment, buildings and operating procedures. However, your organisation may be incurring considerable hidden costs through avoidable waste occurring at random and remaining undetected. Examples could include:

- Timeswitches and other self-actiing controls failing in the 'on' position.
- Maintenance errors, such as fitting an oversized replacement motor.
- Operating errors, such as running an air compressor against a closed isolation valve.
- Lax discipline, for example, leaving auxiliaries to run when not required.
- Leaks.

A management technique called monitoring and targeting (M&T) is the most effective defence against these kinds of loss, which a one-off survey would miss. The next best option – a regular programme of routine energy inspections – would be a more costly exercise, and would anyway miss many kinds of energy-wasting fault because they are frequently of an unforeseen nature.

M&T works by combining regular consumption data (usually weekly or monthly) with corresponding data on production throughput, weather or other driving factors (called 'variables' in the older literature). An M&T scheme is primed with targets for each stream of consumption, these targets being related to the relevant driving factor, so that given the level of activity in the facility, a 'correct' ration of energy can be estimated at each point of use. The deviation between actual and expected consumptions indicates the extent of any unexpected loss, which can then be converted to its implied cost in order to establish its significance.

When a fault detected in this way proves persistent, the pattern of deviation can be analysed as an aid to diagnosis.

An effective M&T scheme provides, in effect, a continuous review of the site's performance, and as well as revealing random unexpected losses, it can be used to monitor and verify the effectiveness of other energy conservation measures. Verification is doubly significant if your company is engaged in emissions trading.

Common Shortcomings

If any of the following apply in your organisation, your ability to manage the consumption of energy will be compromised:

- Unable to provide routine weekly assessment of performance and losses.
- Prime drivers of consumption (eg production flows) not catalogued.
- Quantitative relationship between each consumption stream and its drivers not known.
- 'Best achievable' relationships between consumptions and drivers not used as targets.
- Regular records of driver values not kept in synchronism with consumption data.
- Inadequate sub-metering of significant processes.
- No regular in-house meter readings or other consumption figures.
- No stocktake of bulk-delivered commodities in synchronism with meter readings.
- Analysis and reporting starts afresh each year (instead of being continuous).
- Reliance on crude 'specific energy ratios' as targets for management control.
- Reliance on same-period-last-year as a basis for comparison.
- Focus on percentage deviations (instead of their absolute cost).

- No system for initiating and pursuing investigations into unexplained deviations.

Specialist advice should be sought to rectify any such shortcomings, and thereby maximise the value to be obtained from regular meter readings and other returns.

Case Histories
Steam losses worth P90,000 a year were detected at a paper mill. Someone had left a bypass valve open on a steam trap.

At another paper mill, losses of P130,000 a year were detected when it was found that an oversized replacement motor had been fitted to a vacuum pump following a breakdown.

2.4 ENERGY MANAGEMENT – MAKING A CASE

Most organisations can achieve significant energy savings through low and no cost measures, such as good housekeeping. At some point investment will be needed.

Energy is one of the few cost elements present in the manufacture of every industrial product. It is also one of the key measurable and controllable contributors to cost in at least 80% of all industrial production. Commercially available equipment exists to reduce the Philippines energy consumption by 25%.

Barriers to Energy-Saving Investment
There are three main barriers to overcome:

- The low priority given to energy efficiency in most organisations
- Application of inappropriate standards of investment appraisal
- Decision taken at wrong level in the organisation

Investment appraisal is merely a rational method of making choices. Any healthy commercial enterprise ought to be able to identify more viable opportunities than it can afford to fund. It therefore has to choose which projects are priorities for investment.

Very often energy managers use simple payback as the criterion, even when promoting large projects. More sophisticated methods are needed if the people judging the case, who will usually have an accountancy or business management training, are to take it seriously.

Assessing Costs and Savings
A short energy survey carried out by a consultant can often provide nothing more than indicative payback periods for each recommended energy-saving measure. As the end user (and therefore the potential customer) you are in a better position to get more definite figures, and indeed it is in your interests to do so if your proposal for capital expenditure is to be acceptable. The sources of cost information are, in descending order of preference:

- Estimates or quotations from suppliers
- Knowledge gained from other people who have done similar projects
- Generic estimates from engineers' yearbooks

The Procedure for Calculating Savings is

- Estimate the reduction in unit consumption achieved by each proposed measure. This can either be done as a "before-and-after" calculation (based on, say, a change in running hours) or a percentage reduction can be assumed. Equipment and service providers will often help with such estimates, but check their assumptions and arguments critically – remember they have an optimistic bias.
- Multiply the reduction in units by the unit cost of energy saved. Remember that the cost per unit saved will often be less than the overall average unit price.
- Add any quantifiable incidental savings, such as in manpower, maintenance or capacity charges.
- Note any additional costs which will offset the expected savings.

Assembling the Information

Before making a proposal the energy manager needs to know the following:

- The cost of the proposed work
- Any subsequent recurring costs
- The expected savings
- Risks and incidental benefits
- The criteria against which other capital expenditure projects are assessed

Presenting the Case

An effective proposal will have the following attributes:

- There should be a single unequivocal recommendation (not a selection of choices)
- The full costs must be stated
- Known risks must be disclosed and accounted for
- Against the risks, incidental benefits must be presented as bonuses
- The method of analysing the financial return must be as used for all other projects
- The proposed investment must satisfy the company's current criteria

A proposal will always stand a better chance of acceptance if it can be aligned with the goals of any current corporate campaign. Energy projects for example often have beneficial environmental impacts and can improve reliability.

Topics to look at during the survey/audit fall into 3 different catagories:

- Services – such as lighting, ventilation, boilers, air conditioning, hot water services, compressed air and vacuum systems
- Processes and devices – such as electric motors & drives, fans & pumps, burners, steam systems, mixing and blending, drying, baking and curing, machining and fabrications, treatment booths, hight emperature processes, cooling systems and heat recovery.
- Other – such as mechanical handling, on-site catering and building fabric.

These guidelines give advice on each of these areas in Section 3.

3. SERVICES
3.1 LIGHTING

What to Look For

- People not even knowing where the light switches are
- Tungsten filament lamps running more than four hours per day
- Excessive light levels for the type of work being done
- Large banks of lights controlled by a single switch
- Lack of labels on switches controlling shared workspace
- Outside lights on fixed timeswitch or manual control
- Dirty or discoloured diffusers and shades
- Empty areas lit unnecessarily
- Dirty rooflights or other opportunities to use more daylight
- Artificial lighting in areas with sufficient daylight

Survey Tips and Tricks

- Estimate the lighting load by means of a controlled test with the building unoccupied : read the electricity meter at (say) ten minute intervals first with lights off, then with lights on
- Make a point of examining areas which have had a change of use
- Subject to safety considerations, turn off some lights and see if anyone notices
- Walk the site at night or during shutdowns to see what lights get left on
- An inexpensive light meter will give enough accuracy to establish if lighting is in line with the following 'adequate' levels :

Type of Use	Lux
Close detailed work	1,000 – 2,000
Offices	400
Workshops	300
Stairs and corridors	200
Rest rooms	100
Street lighting	20
Security lighting	5

- Use time-lapse video recording to study intermittently-occupied spaces

Potential Opportunities

- Brief security staff and cleaners to turn off lights when leaving unoccupied areas
- Improve labelling of switches, combined with a staff awareness and motivation campaign

- Replace lamps with more efficient equivalents (eg T12 tubes with T8 tubes if fittings are suitable)
- Convert fluorescent lights to high frequency fittings
- Fit more switches per bank of lights, if wiring permits
- Fit automatic lighting controls (carefully chosen to suit the circumstances) especially in infrequently occupied rooms. Photocells can be used for external lighting.
- Fit more effective reflectors and remove a proportion of lamps.
- In areas where colour rendering is unimportant, use high-pressure sodium discharge lighting.

Case Histories

A cosmetics manufacturer invested P170,000 on automatic lighting controls. Even with today's lower electricity prices the project would have yielded about 20% internal rate of return.

A plastics moulding factory refurbished its very inefficient T12 lighting with T8's at a cost of P96,400 and saved P470,550 a year.

3.2 VENTILATION

What to Look For

- Local extract ventilation likely or able to run when not required
- Eroded or fouled fan blades
- Clogged or obstructed grilles or filters
- Stuck or overridden dampers
- Failure to exploit any existing air-recirculation facilities
- Inappropriate timeswitch settings

Survey Tips and Tricks

- If fans are not visible or audible, air movement can be detected by various means, including improvising with a child's bubble maker. Thin strips of tissue paper can be suspended near extract grilles to provide a more permanent 'tell-tale'
- Pay special attention to areas which have had a change of use where the original ventilation requirements were more demanding
- To make a rough estimate of airflow into a building through an air handling unit (AHU) measure the cross-section of its inlet duct and assume an average air velocity of 1.5 m/s. The AHU may also carry a rating plate stating its design capacity. Commissioning test reports may exist.
- In the absence of other evidence, assume air handling plant was designed to prevailing design codes for the type of use.

Potential Opportunities

- Interlock local extract ventilation to occupancy and/or activity.
- Where dampers are used to control air flow rates, consider variable speed control of the fans (or even just two-speed motors) instead
- Fit high-efficiency motors to fans
- If excessive ventilation rates are confirmed, reduce fan speed by changing pulley ratios.

Case History

A pigment manufacturer was discharging extract air containing water vapour and traces of fine powder. A spray condenser, fitted at a cost of P2,840,000 recovered the heat and scrubbed the powder from the extract air. At today's fuel prices the investment would have realised an internal rate of return close to 50%.

3.3 BOILERS

Note: this section deals with water-circulation boilers only, as commonly found on industrial heating systems. For issues specific to steam boilers and steam boilers see sections below.

What to Look For

- Damaged or insufficient insulation on boilers and associated pipework, valves or flanges
- Check for water losses by assessing the water make up rate, which should be zero.
- Check whether multiple boilers are sharing low loads, when one unit ought to suffice
- Could boilers be running when there is no demand other than their own standing losses?
- Check if idle boilers are dumping heat up the chimney/flue
- Is heating-boiler time control dictated by hot=-water service preheat time.
- See also the section on burners

Survey Tips and Tricks

- A significant system-water leak will be evident from the continual filling of the feed and expansion tanks
- Low leakage volumes can be detected by suspending a small weighted container (such as a seaside bucket) under the ball-valve spigot. If subsequently found full, it signifies that the feed-and-expansion tank must have been emptying
- To assess the degree to which boilers are oversized and therefore likely to be incurring avoidable standing losses, observe their firing cycles with a stop-watch for about an hour, noting the ignition and shutdown times for each boiler.
- To assess whether idle boilers are dumping heat up the chimney, check for air flow through the boiler, and if confirmed, measure the stack temperature to see if it is elevated (this technique is not always practical)
- Check water temperature in off-line boilers to confirm that they are isolated. If feeding a common flow header, relate common flow temperature to individual boiler flow temperatures to estimate the proportion of flow through idle boilers.

Potential Opportunities

- Isolate boiler capacity in excess of peak requirements, fitting isolation valves if necessary
- Fit flue dampers if heat loss from idle boilers cannot be prevented by other means
- Rectify faults in boiler sequence control if low heating loads are being shared by more than one boiler
- Improve control so that boilers are only enabled when there is demand from one or more of the circuits served
- Optimise high/low firing sequences to minimise the number of ignition purge cycles
- Apply weather-compensated boiler temperature control if feasible

- Fit one condensing boiler to operate as the lead unit or
- Evaluate a small combined-heat-and-power (CHP) unit to substitute for the lead boiler

Case History
A water company had numerous old cast-iron heating boilers. It conducted a campaign to improve combustion efficiency through a standard retrofit modification. The same project at today's fuel prices would yield 70% internal rate of return.

3.4 AIR CONDITIONING

What to Look For

- Excessively-low cooling set point (say below 22°C)
- Lack of time control, excessive hours of operation, or risk of time-scheduling being overridden
- Excessively tight control of relative humidity
- Blocked filters
- Uninsulated supply ductwork
- Portable electric heaters
- Frost on pipework and fittings
- Air-recirculation potential not exploited
- Ventilation outside working hours (other than for free cooling benefit)
- Risk of simultaneous heating and cooling
- Risk of doors and windows being left open, holes in building structure, or other infiltration routes
- Risk of air exchange with non-conditioned spaces
- Fouled evaporator or condenser coils
- Electrical appliances (eg computer monitors) and lighting running unnecessarily

Survey Tips and Tricks

- Log chiller run hours regularly to detect running during cool weather
- Observe operating patterns of air conditioning chillers, cooling towers etc, relative to outside conditions; look for excessive running or frequent on/off cycling
- Compare refrigerant suction/discharge temperatures and condenser water temperatures on similar plant items. Significant differences may point to physical problems or incorrect settings.

Potential Opportunities

- Discontinue control of relative humidity if possible
- Consider alternatives to electric evaporative humidifiers
- Increase air re-circulation
- Make maximum use of fresh air for cooling, including pre-cooling at night
- Implement enthalpy control

- Selectively inhibit out-of-hours ventilation to optimise energy requirement
- Provide ‘spot cooling’ systems for zones with year round cooling requirement, so that the main central system need only be operated seasonally.

3.5 HOT WATER SERVICES

What to Look For

- Long runs of uninsulated hot water pipework
- Hot taps being allowed to run to overflow
- Hot water being used where cold water would suffice
- Poor insulation on hot water storage vessels
- Excessive temperatures at hot taps (unless essential for control of legionella)
- Unreasonable quantities of hot water being used (see Survey Tips and Tricks below)

Survey Tips and Tricks

- If a hot water cylinder is fed from its own break tank you may be able to estimate the draw-off rate by shutting off the rising cold feed and timing the fall in water level.
- Clamp-on ultrasonic flow meters can be hired but are very prone to error and should be calibrated in situ, at least approximately
- When measuring hot water flow, remember to account for secondary recirculation if necessary
- Run a hot tap which has not been used for a while and time how long it takes to deliver hot water
- Establish the number of full-time-equivalent occupants and how they use hot water, in order to estimate their requirements

Potential Opportunities

- Fit point-of-use water heaters in order to dispense with central storage and long distribution runs. These may be wall-mounted electric types in washrooms, or direct gas fired for catering and other larger users
- Fit flow restrictors to wash hand basins
- Fit time control to point-of-use heaters, immersion-heater elements, and secondary circulation pumps
- If HW is generated from main heating boilers, consider alternative heat source for use outside heating season
- If central HW generation is to be retained look for alternative heat sources such as hot process drains (beware contamination risk), flash steam or hot condensate
- Rationalise multiple storage cylinders if demand is low relative to stored volumes
- Recover heat from water-cooled equipment and processes

3.6 COMPRESSED AIR SERVICES
What to Look For

- Air leaks; particularly on connectors, flanges and flexible hoses
- Are compressors running when there is no demand for air?
- Air intakes drawing in warmer air than necessary. Use the coldest possible air source to maximise compressor efficiency
- Inappropriate uses. Low-grade duties (like swarf blowing, or agitating liquids in tanks) do not warrant clean, dry air from the central system.
- Excessive distribution pressure. Higher pressure means greater losses through leaks and higher power requirement for the same delivered air volume.
- Dead legs on distribution pipework. These present a leakage risk
- Safety valves operating frequently, or leading continuously
- Manual drains left cracked open

Survey Tips and Tricks

- Look and listen. Are air-pressure safety valves operating? If so, control is inadequate. Can you hear air escaping during meal breaks and after hours? Are compressors starting and stopping frequently?
- If the compressors have hours-run meters, read them all at intervals through the day to see whether you have more units running than necessary.
- Compare on-load hours against total run hours to check for idle running
- If the air supply is metered, read regularly through the day to establish patterns of use relative to production activity. Look for unexplained idle losses
- Air meters can be unreliable. If a meter provides a chart recording, look for symptoms such as the trace being unexpectedly smooth, clipped off at maximum, or never returning to zero
- After hours, shut off the compressors and either (a) record the rate at which pressure subsequently falls or (b) time the load/unload periods
- A 10% air loss might be considered acceptable
- Power delivered to air tools is ten times the cost of electricity to do the same job
- Reducing air inlet temperature by 6^{0C} increases output by 2%
- Ask how often the filters are replaced. Blocked filters cause pressure drop.

Potential Opportunities

- Use low pressure blowers for applications such as air knives, air lances, air agitation, blow guns, product ejection, powder transfer etc
- Control pressure at the point of critical demand, not necessarily at the compressor

- Divert compressor cooling air to where heat is required. Look for a nearby application which could benefit from air preheat. Even preheating boiler combustion air is beneficial
- Heat rejected from oil coolers can assist hot water generation
- Fit improved control of central compressors. Computerised sequence controls could reduce compressor run hours and prevent air loss and wasted power through pressure overshoot
- Fit zone-isolation valves. These can be under time control, or interlocked to the packing/production line served, to enable parts of the site to operate out of hours without air going to the whole works. If combined with a pressure gauge, local leakage tests would be possible
- To permit zone-isolation it may be necessary to rationalise air supply lines to eliminate cross-feeds between different production units.
- Install local air blowers for low-grade duties, for example, liquid agitation, where low pressure and high volumes of air are required without drying or filtering. A separate blower reduces demand on the central system and may permit a pressure reduction or reduced operating hours.
- Substitute alternatives for air tools. Would the operators prefer electric tools (especially cordless ones) capable of doing the same job? This is most beneficial where a whole zone of air supply can be cut out. But note: cordless tools are attractive targets for theft
- When production is shut down, isolate constant bleed pneumatic controls
- Use actuators to time blowers instead of constant air flow
- Use specially-designed nozzles for blowing applications
- Replace timed receiver drains with water-sensing or float traps
- Switch to high-performance lubricants
- Consider high-efficiency motors and variable-speed drives.

Case History
In 1999 a vehicle manufacturer spent P320,000 on an automatic sequence control of its air compressors. Although electricity was then more expensive in real terms, the same project today would still yield an internal rate of return of 70%.

3.7 CENTRAL VACUUM SERVICES
What to Look For

- Air getting in through leaks
- Ineffective closure flaps on vacuum hoses
- Oversized nozzles on hoses
- Redundant legs of vacuum pipework
- Manual on/off control, with risk of out-of-hours running
- Seal water running to drain from liquid-ring vacuum pumps

Survey Tips and Tricks
Run vacuum pumps against shut-off conditions, and measure air flow in the outlet duct. This equates to upstream air in-leakage. Measure

vacuum at inlet manifold under these conditions and compare with manufacturer's load curve. Low vacuum at the measured flowrate indicates loss of pump efficiency.

If necessary, a manometer for low pressure differentials can be mprovised from a length of transparent tubing bent into a "U" with water in the bottom, but beware any risk of water getting into the measured system.

Repeat these measurements at appropriate intervals (quarterly or annually) depending upon the degree of risk.

Potential Opportunities

- Install variable-speed drive controls on vacuum manifold pressure
- Consider refrigeration circuits for liquid-ring water cooling
- Replace vacuum-pump motors with high efficiency equivalents
- Upgrade complete vacuum pump sets with more efficient units during replacement
- When vacuum is provided for local cleaning of components and assemblies at workbenches, alternative methods (eg dedicated local systems or even brushes and pans) may be feasible (but consult the user)
- Increase system working pressure

PROCESSES AND DEVICES

3.8 ELECTRIC MOTORS AND DRIVES

What to Look For

- Driven equipment not doing a useful job
- Oversized motors
- Risk of unnecessary running
- Voltage imbalance, low or high voltages, harmonic distortion or poor power factor
- Unusually hot or noisy gearboxes
- Worn or slack V-belts
- Individual belt broken on multi-belt drive
- Misaligned pulleys or couplings
- Worn bearings in motors, driven equipment, or intermediate drive train

Survey Tips and Tricks

- Start with the largest motors and longest running hours first
- Pay particular attention to the noisiest machines
- 3-phase motor power is derived from the ammeter reading (I) by the following formula, where V is the supply voltage and PF is the power factor (typically 0.8 – 0.9)

  $$\text{Power} = \frac{\sqrt{3} \times V \times I \times PF}{1000} \quad \text{(kW)}$$

  Compare the result with the motor's nameplate rating to see if it is only part-loaded.
- Thermal imaging equipment can help pinpoint frictional transmission losses

Potential Opportunities

- Introduce time switching
- Fit automatic stop/start control (this might include motor load sensing)
- Substitute a high-efficiency motor when replacement is necessary
- Consider soft-start controllers for intermittent running motors
- Reduce losses in the driven equipment
- Change pulley ratios to run driven equipment at optimum speed
- If permanently lightly-loaded, switch to permanent star connection or fit a smaller motor
- On a part-loaded multi-belt, remove one or more belts to leave only the minimum required for the power actually being transmitted
- Consider variable speed drive or multi-speed motor depending on the circumstances
- Where the duty toggles between high and low load, consider replacement with a multi-speed motor (up to four load steps may be accommodated by MSM)
- When V-belt pulleys need replacing opt for wedge belts (2% improvement) or synchronous, flat or ribbed belts (5-6% improvement)

- Where possible, replace gear boxes with variable speed direct drives
- Adopt high-performance lubricants

Case History
Changes at a food manufacturer had left them with excessive capacity on a pneumatic conveying system. They spent P580 on a new pulley for the blower (to reduce its speed from 2,420 to 1,700 rpm) and claimed annual savings of P49,600.

3.9 FANS AND PUMPS
What to Look For

- Unintended recirculation paths
- Oversized motors
- Excessive fan/pump speed
- Excessive system resistance (for example because of dirty filters, stuck valves or dampers)
- Unbalanced distribution networks with excessive flow in some branches at the expense of others being starved of flow

Survey Tips and Tricks

- Measure the flow and inlet/outlet pressures. Compare them not only with manufacturer's data but with system design intent
- Air movement can be detected with tissue paper, a smoke generator, or even a child' bubble maker
- Compare the performance of identical duty and standby units

Potential Opportunities

- Where fans and pumps have variable duties (controlled by dampers or valves), variable speed drives should be considered as an option
- Inlet dampers are preferable to discharge dampers
- Where fans or pumps are operating continually at part load, consider reducing the impeller size or changing the speed by using a different drive ratio
- Avoid sharp bends in ducts or pipework and consider low-friction pipework when refitting
- On a pumped distribution network, reduce general supply pressure and use a small booster pump for the index circuit
- Rebalance any distribution system in which throttling valves or dampers are being used to regulate flow, so as to achieve design flow in all branches with the minimum total flow
- On primary heating and chilling systems, replace three-port diverting valves with two-port valves and use variable-speed control of pumps to regulate pressure

Case History
An airport operator fitted variable-speed drives to chilled-water circulating pumps in 1999, achieving payback of a P500,000 investment in just under

two years. Even at today's lower real electricity prices, payback would still be less than three years, with an internal rate of return approaching 30%.

3.10 BURNERS

What to Look For

- Poor burner tuning resulting in flue losses through excess air or unburned fuel (evidence by yellow flame, soot in flue-ways etc_
- Unusual-shaped or unstable flame
- Flame impingement
- No probe-hole in exhaust flue, making combustion tests impossible
- Results from earlier combustion tests chalked up nearby
- Combustion results identical from one test to another
- Combustion test reports where the reported efficiency is inconsistent with measured parameters

Survey Tips and Tricks

- If testing for combustion efficiency by means of $C0_2$ percentage, remember to test for smoke (in the case of oil and solid fuel) and carbon monoxide (in the case of gas). Without these measures it is impossible to say whether a given percentage of $C0_2$ represents lean or rich combustion; a rich mixture will cause losses in unburned fuel.
- Compare similar units. Is one appreciably better than the others?
- Where several items of combustion plant discharge into a common flue, beware the effects of variable suction. Record draught-gauge measurements.
- With pressure-jet oil burners, ask when the nozzles were last cleaned or replaced. It is often economical to replace them at every service; whereas 'cleaning' usually damages them.
- Look for hot spots on casings (may indicate impingement or refractory damage)
- Time on/off/purge cycles

Potential Opportunities

- Locate a source of preheated combustion air, such as the exhaust from a dryer or other waste heat, or even just ducting from the roof space. But note : if preheat is not consistent, this can cause the air:fuel ration to vary
- Consider direct recuperation
- Reduce burner ratings to reduce stack exit temperature and minimise on-off cycling; or consider high/low or modulating burners
- Use a larger number of smaller, self-proportioning burners
- Improve combustion control; consider oxygen-trim control
- Pressure-regulation of combustion chambers enables tighter adjustment of air:fuel ratio

- In some high-temperature furnace applications, using pure oxygen instead of air can be economical and may for example give a hotter flame or better product quality

Case History
In 1998 an engineering company installed recuperative burners, improved burner control, and fitted low-thermal-mass insulation to a heat treatment furnace. P210,000 investment was recovered in 1.5 years and the indicative internal rate of return at current fuel prices is just under 50%.

3.11 STEAM SYSTEMS

What to Look For

- Steam leaks
- Missing, wet or damaged insulation
- Flooding in pipe ducts
- Steam traps passing steam
- Steam traps not passing condensate
- Condensate running to waste
- Flash steam being lost from receivers and hotwell
- Dead lengths of pipework, or long runs of pipework with very small users at the end
- Potential water pockets caused by concentric reducers, large globe valves or wrongly-fitted strainers
- Group trapping (several heat exchangers sharing one trap)
- Bypass valves on traps (not strictly necessary and may be left cracked open)
- Manual temperature control of process items
- Condensate overflowing to waste at collecting points
- Pipework which does not have a fall towards drain pockets
- Low feed tank temperature
- Manual control of dissolved solids
- Unnecessarily-low total dissolved solids
- Insufficient reserve volume in feed tank to accommodate peak condensate return during start-up

Survey Tips and Tricks

- Ask the boilerman about the frequency and quality of maintenance
- Steam traps may be fitted with sight glasses to verify operation
- Thermodynamic traps may be heard opening and closing frequently
- It may be possible to divert condensate temporarily downstream of the trap, into a bucket or barrel. Note the volume or weight at intervals, as a means of estimating steam demand. The weighing vessel must contain cold water because of the potential hazard of flash steam from the condensate
- If condensate is pumped from a receiver of known volume, intermittently, timing the pumping cycles will provide a load estimate

- Check the temperature of condensate pipework after each trap. If significantly below 100^{0}C, the trap is not working
- Put a temperature logger on blowdown pipework to record timing and duration of blowdown
- Estimate the percentage of condensate returned to the boiler
- Ineffective insulation in underground ducts can manifest itself through the ground drying unusually quickly after rain.

Potential Opportunities

- Consider dispensing with steam and adopting alternative heating techniques
- Rationalise pipework to reduce distances travelled (and reduce diameters where feasible)
- Make alternative provision for small loads at the ends of long dedicated pipe runs (or relocate them)
- Insulate fittings
- Find a use for flash steam (eg sparging it into the feedwater tank or cascading to lower-pressure users) or use condensate coolers on calorifiers and heater batteries where feasible
- Fit thermostatic air vents to reduce warming through times
- Measure warming-up time to establish the minimum necessary
- Eliminate bypass valves on steam traps and if necessary fit better-matched traps
- Fit automatic temperature controls in place of manual valves
- Use an engine or turbine for pressure reduction
- Reduce steam pressure if possible, to give improved performance and less flash-steam loss
- Recover heat from boiler blowdown
- Implement automatic TDS control on boilers
- Reduce boiler pressure
- Put a lid on the feed tank
- Increase feed temperature to aid oxygen removal, reduce dosing requirements and resultant blowdown
- Where steam is exclusively used at high pressure and there is no use for flash steam, consider using CBA pumps in a pressurised condensate return loop directly injected into the boiler feedwater
- If condensate is all dumped because of potential contamination risk, fit automatic quality measurement to control a dviverting valve and recover what is safe to reuse

Case Histories

A tyre manufacturer installed flash steam recovery and improved condensate collection, cutting boiler make-up from 70% to 10%. The project cost P200,000 and (including the incidental savings on boiler make-up water and chemicals) would yield an internal rate of return exceeding 100% at today's fuel prices.

A chemical company spent P210,000 insulating pipe fittings in 1996, achieving a nine month payback period (equivalent to an internal rate of return of 170% at today's values).

A food ingredients manufacturer noticed that a fluidised-bed spray dryer was the only unit needing steam overnight. They fitted a standby electric *air heater for overnight use, and proceeded to recover the P13,500 installation cost eight times a year.*

3.12 MIXING AND BLENDING

What to Look For

- Manual control of batch blending operation with inadequate end-point detection
- Unnecessarily long mixing times
- Lax ingredient control
- Blade wear (increases mixing time)
- Inadequate insulation on mixing vessels
- Use of compressed air to agitate mixtures

Survey Tips and Tricks

- Record mixing times and look for suspicious inconsistencies
- Question the nature and frequency of end-point tests
- Try to identify physical properties which could be used to determine completeness

Potential Opportunities

- Convert to low-loss stirrers
- Fit high efficiency motors
- Optimise stirring speed
- Improve end-point detection and control
- Use soft start motor control
- Consider intermittent rather than continuous mixing
- Convert batch mixing processes to continuous

Case Histories
A manufacturer of rubber seals put a soft-start motor controller on a 100 kW mixing mill motor which was operating four minutes on, six minutes off. The P16,000 investment (1995 prices) was paid back twice in the first year.

3.13 DRYING

What to Look For

- Product overdried
- Manual control of end-point at operators' discretion
- Raw material moisture higher than necessary, for example because of damp storage conditions
- Excess airflow into driers
- Hot external surfaces on driers (missing insulation)
- Driers actually running empty, or able to do so
- Air filters clogged or ripped
- Air leaks into or out of the drier
- Airflow imbalance on multiple tunnel driers (evidenced by wet or overdried product from different driers)

Survey Tips and Tricks

- In direct-fired driers, variations in exhaust oxygen content will indicate the degree of dilution by air ingress
- Measure the moisture content of the dried product as it enters the next process stage, especially if it goes through a buffer store. Drying below this 'natural regain' moisture level is pointless
- Measure the energy input per kg of water evaporated. Compare this against drier manufacturer's data sheets, or one drier against another
- Repeat the measurement from time to time to guard against future deterioration in performance
- In theory a perfectly efficient drier would require only 0.63 kWh of input energy per kg of water removed

Potential Opportunities

- Prevent accidental moisture gains to feedstock
- Mechanical de-watering (pressing, centrifuging etc) can reduce the need for thermal drying
- Preheating the feedstock may aid drying
- Avoid high air supply temperatures and use more air if necessary
- Insulate drier casings to reduce heat loss
- Fit recirculation fans to improve internal velocities, reduce dead spots, and maximise relative humidity in exhaust
- Recover heat from exhaust air. If contaminated by dust etc, consider use as preheated combustion air
- Control drier end-point automatically, for example on exhaust relative humidity
- Two stage drying may be more economical when the product contains both large and small particles
- Investigate whether the output dryness specification can be relaxed
- Are you drying product to stabilise for storage pending subsequent processes which add water?
- Mechanical de-watering of powders (and subsequent drying) can both be accelerated by reducing the proportion of fines
- Where product is conveyed on perforated belts or trays, reduce the blank supporting area under the product
- Increase air velocity over the product
- Subdivide or granulate the product
- In direct-fired driers, if dilution air is introduced before the combustion zone, mix it after the combustion zone instead to avoid flame chilling
- Cascade chamber driers from dry through intermediate to wet, reheating as required to avoid condensation
- Reduce supply air temperatures over weekend closures if full of partially-dry product
- On major processes use mechanical vapour recompression to recover exhaust heat
- Consider matching co-generation (CHP) to a continuous drying system

Case Histories

A chinaware manufacturer dispensed with 'open-shop' drying in favour of a microwave/vacuum drier costing P5,620,500. The investment would have yielded an estimated 45% internal rate of return at today's prices.

A major sugar factory implemented model-based predictive control of driers in 1996. The project gave energy savings, increased yield, and quality improvements which at today's fuel prices equate to an internal rate of return of 120%.

An animal-feed producer eliminated some driers completely by rebranding the product and selling it undried.

3.14 BAKING AND CURING

What to Look For

- Part-loaded ovens or autoclaves
- Excessive equipment preheat times
- Oven doors left open longer than necessary
- Air ingress especially at seals, sightholes, access panels
- Potential useful heat gains to surrounding space
- Plant in unnecessarily cold or exposed location
- Incorrect damper settings
- Excessive exhaust volumes

Survey Tips and Tricks

- Use a datalogger to record local air temperature above oven doors

Potential Opportunities

- Optimise loading schedules to operate equipment for shorter periods at full capacity
- Use combined heat and power
- Review supply options, eg, substitute gas for steam or radiant tube; electric radiant; microwave; gas radiant etc
- Fit curtains to tunnel-oven entrances

Case History

An aerospace components manufacturer operated a large autoclave for curing resin-bonded components in relatively small batches. By rescheduling operations to run it fully loaded, they not only reduced energy costs, but cut 70% off their nitrogen demand.

3.15 MACHINING, FORMING AND FABRICATION

What to Look For

- Auxiliaries such as hydraulic packs, coolant pumps, waste removal etc running on idle machines
- Hydraulics, compressors, chillers and other services or auxiliaries able to run when main machine is idle
- Uninsulated cooling systems

- Dirty skylights
- Blunt tooling
- Open or slow-acting vehicle access doors
- Incorrect temperature settings on product cooling or baking
- Worn extruder screw surfaces

Survey Tips and Tricks

- Fit run-hours meters (if not already present) and reconcile running hours of auxiliaries against work schedules
- Compare similar machines and use the fastest or most efficient as the benchmark
- Canvass the views of machine operators
- Observe operations during meal breaks and other quiet periods

Potential Opportunities

- Interlock auxiliaries to the main machines which they serve
- Use machines with lowest specific energy consumption
- Fit high-efficiency motors when replacing failed ones
- Replace centralised heat supply with locally controlled gas radiant heaters
- Fit power-factor correction capacitors if necessary
- Implement zoning and variable speed pumps on central cutting-fluid systems
- Recover waste lubricating oil for use as heating fuel
- Fit quick-acting doors for vehicle access
- Redecorate in lighter shades for improved illumination
- Fit destratification fans in high-bay buildings
- Insulate barrels of plastics extrusion presses
- Change to near-final-size castings
- Variable-speed AC drives to replace failed DC drives (for example on filament or film uptake drives)
- Variable-speed drives on hydraulic packs to limit pressure or spill-back when off load
- Optimise source of compressed air for blowing (eg poly bottles)
- Soft-start motor controllers
- Additives to assist flow of polymers
- Improved lubrication

Case Histories

A company making metal pressings spent P6,300 on controls which automatically turned off motors on presses which had been idle for a preset period. At today's prices the project would have yielded close to 100% internal rate of return.

An injection moulding company put heat shields around heated press platens at a cost of P20,000. At today's prices this project's internal rate of return would have been about 200%.

Another injection moulding company spent P5000 in early 1995 on timers to turn off the heaters on idle presses. They recouped their investment once a month thereafter.

3.16 TREATMENT BOOTHS AND CABINETS

What to Look For

- Lighting or air extract running, or able to run, when not required (Note : containment booths need to run continuously)
- General ventilation relied on where local extract could be applied
- Local extract systems drawing heated air from surrounding space
- Inadequate insulation if heated or cooled
- Defective seals where airtightness is needed
- Common air extract from multiple cabinets
- Unnecessarily high air extraction rates

Survey Tips and Tricks

- Use smoke generator or strips of tissue to track air movement
- Use the site's list of local extract ventilation (LEV) equipment as a checklist
- Observe pattern of use, especially during breaks

Potential Opportunities

- Arrange air extract and cabinet lighting to run on demand, with automatic switch-off
- Recover exhaust heat
- Arrange dedicated extract for lightly-used cabinets
- Install dedicated fresh air supply ducts to avoid drawing in heated air
- Implement reduced or variable fan speed
- Fit more-efficient fans

3.17 HIGH TEMPERATURE PROCESSES

What to Look For

- Evidence of unnecessarily long preheat periods
- Unnecessarily high processing temperatures
- Extended holding periods at high temperature (for example while awaiting results of chemical analysis on product)
- Batch process plant maintained at temperature between charges
- Batch oven/furnace doors left open for longer than necessary
- Evidence on external casing of hot gas leakage
- Product allowed to pick up moisture between drier and kiln

Survey Tips and Tricks

- A thermocouple on the end of a pole can be used to check surface temperatures on large plant
- Use infra-red thermography to detect hot spots
- Compare actual energy ratio per tonne with theoretical requirement based on specific heats and temperature rise

Potential Opportunities

- Maximise hearth loading
- Automatic pressure control of furnaces permits tighter control of combustion efficiency
- Reduce furnace temperatures if excessive
- If heavy refractory lining is used in an intermittent furnace, replace inner face with a ceramic-fibre insulation blanket or tiles
- Move stock into heated space if stored outside; preheat further if suitable waste heat sources are available
- Where parts need to be reheated for successive operations, use insulated transit containers
- Fit permeable radiation walls in furnaces
- Recover heat from exhaust
- Reduce the mass of refractory furniture in tunnel kilns
- Optimise speed of kilning
- Use direct gas firing if possible on furnaces with radiant tubes, or electric induction for metal heating or melting
- Reduce air ingress into tunnel kilns using end doors
- Ensure sand traps, create an effective seal
- Subject to product requirements, aim for lowest oxygen content at exhaust
- Use hot-gas recirculation to reduce temperature stratification and promote heat transfer to product
- Transfer clay goods direct to kiln from drier to avoid moisture pickup

Case Histories
A forge installed a fluid-bed furnace for heating bar ends, replacing a less efficient conventional furnace. Their investment of P450,000 in 1994 offered a payback every eight months, which translates into an internal rate of return of 70% (in today's terms).

A glass container manufacturer installed recuperative heat recovery at a cost of P160,000, giving a present-day internal rate of return exceeding 80%.

3.18 COOLING SYSTEMS
What to Look For

- Fouling of cooling tower
- Uninsulated pipework and fittings
- Excessively low chilling medium temperatures
- For an air-cooled condenser, check for short-circuit air path to evaporator inlet
- Air bypass or recirculation in cooling towers
- Fouled coils, air filters, air inlet screens or cooling tower spray nozzles
- Excessive cooling water flow rate and hence pumping power
- Abnormal temperatures or pressures in refrigeration circuit; avoid low evaporating temperatures
- Multiple cooling towers with more units runn ing than necessary

Survey Tips and Tricks

- The temperature efficiency of a water cooled condenser can be checked against the manufacturer's specification
- Measure refrigerant liquid temperature upstream and downstream of the strainer. A high differential implies clogging
- Excessive cooling water flow rate can be inferred from lower-than-expected temperature rise

Potential Opportunities

- Inhibit chillers below a certain ambient temperature, or exploit other free cooling potential
- Satisfy localised winter cooling demand with dedicated package chillers instead of a central system
- Fit a chiller load management system
- Raise the chilled water temperature to its feasible limit
- Where duty is shared by diverse chillers, optimise by letting the best take the lead
- Use thermal storage to smooth the load profile, reduce start/stop cycling, maximise use of most efficient chiller, and possibly stand down excess capacity
- Buy in liquid nitrogen rather than generating on site

Case History
An acid manufacturer installed heat recovery on an exothermic process at a cost of P510,000. The equivalent internal rate of return in today's terms would be 10%.

3.19 HEAT RECOVERY

What to Look For

- Fouled heat exchangers
- Fans fouled, worn or even stopped
- In air recirculation systems, verify operation of control dampers
- Incorrect configuration or control of batch heat reclaim
- Lost fluid or failed pumps in run-around coil system
- Dumping of heat because of mismatched sources and loads

Survey Tips and Tricks

- Check temperature differentials against manufacturer's specification or original design intent
- Compare temperature efficiencies of similar units
- Note the temperature and heat content of the high-temperature stream at outlet, in case there is potential for further heat recovery

Potential Opportunities

- On HVAC, inhibit heat recovery between 16-24^{0}C to prevent heat gain to chiller plant
- Consider variable-speed drives on fans and pumps

- Fit thermal storage to improve utilisation where heat is being dumped because of mismatched supply and demand profiles

Case Histories
An animal-feed producer had bypassed a heat recovery unit because it was fouled and thought to be beyond repair. An enterprising employee devised a method of unblocking it, which was done at a cost of P10,000 including equipment hire. Once recommissioned, it resumed saving P300,000 a year.

A dairy ran into a constraint on increasing output because it appeared to be short of chiller capacity for cooling the milk output from its pasteurisers. However, on investigation, it was found that the pasteuriser's regenerator was performing well below industry norms. The regenerator partly cools the milk output by exchanging heat with the cold input stream. By improving the regenerator heat exchanger, at a cost of P250,000, the company obviated the need to spend P1,500,000 on a new chiller and incidentally saved P100,000 a year on electricity.

OTHER ENERGY SAVING OPPORTUNITIES

3.20 MECHANICAL HANDLING
What to Look For

- Conveyors running empty
- Motors running lightly loaded
- Compressed air used for positioning or sorting without proper nozzles
- Compressed air bleeding during inactive periods
- Electric trucks charged during daytime tariff period

In pneumatic handling systems:

- Dust on fan blades or filters
- Air leaks
- Transport velocities higher than necessary

Survey Tips and Tricks

- Use infra-red thermography to detect hot spots caused by friction
- Listen for air being discharged when handling system is idle
- Stand and watch during production, at breaks and during shift changes

Potential Opportunities

- Reduce the thermal capacity of conveying equipment and transit containers which go through heating or chilling equipment
- Optimise carrying capacity; use buffer stores to isolate from downstream stoppages
- Reduce distances and minimise or eliminate vertical lifts
- Use control with sensors to enable conveyors to run only on demand (ideally combined with short runs)
- Manually control to run intermittently at full load rather than continuously at part load or empty

- Replace pneumatic conveyors with bucket conveyors or other mechanical alternatives
- Apply low-friction coatings to conveyors
- Where conveyors pass through heated process equipment, insulate the return leg, route it through the heated equipment, or cool it to preheat air
- Where product passes from heating to cooling zone, use separate conveyors
- Fit purpose-designed nozzles and isolating valves to air jets
- If possible, charge truck batteries overnight; if this is not possible, at least avoid charging on winter weekday afternoons

3.21 ON-SITE CATERING
What to Look For

- Kitchen ranges turned on before they are needed
- Kitchen ranges used as source of space heating
- Vending machines running 24 hour per day
- Badly-fitting door seals on refrigerators and freezers
- Hot water left running into kitchen sinks
- Kitchen ventilation fans drawing heated air from dining area
- No 'night blinds' on chilled display cabinets
- Ovens and sterilisers preheated for excessive periods
- Dishwasher running part-loaded or empty
- Fridges and freezers next to heat sources
- Inadequate ventilation for condenser units of cold rooms
- Heated cabinets or counter display lighting left running
- Vigorous boiling of un-lidded pans

Survey Tips and Tricks

- If kitchen supplies are sub-metered, take frequent readings throughout the day to establish patterns of demand
- Visit directly after meal time to see if cooking equipment is still running
- Observe activity during preparation period at start of working day
- Gas consumption during summer months may indicate catering demand

Potential Opportunities

- Provide energy training for catering staff
- Fit soft-start motor controllers on freezers, refrigerators and chilled display cabinets
- Fit 'night blinds' on open chilled display cabinets
- Control vending machines, bains maries, heated cabinets and counter lighting by timeswitches
- Heat recovery from kitchen extract
- Motor controllers on refrigerators and freezers
- Provide efficient fixed water boilers to obviate the need for kettles
- Replace conventional ovens with microwave cookers in mess rooms

3.22 BUILDING FABRIC
What to Look For

- Poorly-utilised space
- Doors and windows propped open
- Broken windows and rooflights
- Dirty windows and rooflights
- Holes in walls or roof
- Substandard or damaged insulation
- Damp which may have compromised existing insulation
- Substandard or damaged draughtproofing

Survey Tips and Tricks

- An infra-red camera can be used on cold nights to detect hot spots (from outside) or cold spots (from inside)
- A bubble-maker or smoke generator can be used to sense unwanted air movement
- A building's heat loss characteristics can be estimated from the rate of temperature decay at the end of the working day, taking outside temperature into account

Potential Opportunities

- Repair holes and broken windows
- Apply draughtproofing
- Apply insulation
- Clad and insulate over rooflights
- Fit air-locks or high-speed doors

Case History
In 1995 a steel company applied sprayed insulation to a corrugated roof. Their investment of P2,350,000 would have yielded a 10% internal rate of return at current fuel prices.

4. REPORTING YOUR FINDINGS

4.1 SITE ENERGY CONSUMPTION AND EXPENDITURE

A tables like the one shown below can be used to record information about annual energy consumption and expenditure. They are typical of the background information which would normally be recorded in a survey report.

Site Total Statistics (actual)

A table in this form could be used to record statistics for at least the most recent year, and preferably two years. The 'quantity purchased' and 'cost' columns can be completed by aggregating data from invoices for the year(s) in question. The $C0_2$ figure must be derived by applying the conversion factors shown below, if necessary first converting quantities into kWh units.

Major Energy-Using Equipment

Where possible, you should estimate the annual energy used in major plant items (or in services such as heating or lighting). This will later help you to estimate likely savings. Where dedicated submeters are not fitted, it may be possible to infer consumption from the equipment nameplate rating, by making assumptions about annual running house. Note that some equipment may be fitted with hours-run counters to facilitate this.

The cost column can be calculated by multiplying the un its consumed by the prevailing price. To avoid overstating any likely savings, it is better to use the marginal unit price rather than the average cost per unit of energy. The marginal price is the amount saved by consuming one un it less than expected.

		Year: January to December 2006			
Energy Source	Units	Quantity purchased	KWh converted	Cost (P)	CO_2 (kg)
Electricity	kWh	46,789,012	46,789,012	18,715,600	20,119,000
Gas	KWh	9,876,543	9,876,543	790,120	1,876,000
Oil	Litres	23,400	248,040	46,800	6,000
LPG	kg	5,000	68,900	9,200	9,000
		Totals	56,982,495	19,561,720	22,010,000

4.2 REGISTER OF SOURCES OF DATA FOR CONSUMPTIONS AND THEIR 'DRIVERS'

These tables provide a site-specific record detailing the sources of data which might be needed for analysis or for future regular monitoring. Although not essential for the purposes of the survey, completing tables like these is good practice and will at least help to ensure that all the requisite information could be obtained if needed later.

Failure to account for 'drivers' (the things which determine demand), when analysing patterns of energy consumption, is a prevalent management fault.

These tables are provided as templates, and may not give you enough room for your entries. You should prepare your own versions with more appropriate layouts, and with provision for more than the four entries illustrated here.

Note : The tables refer to EACs (energy accountable centres). Some managers notionally split their businesses into EACs to improve energy accountability. An EAC usually has these attributes :

- The ability to measure energy flows into it
- The ability to measure production output from it (or some other determinant of demand)
- A person accountable for the energy used

Consumption Drivers

Energy consumption depends upon the amount of work being done – be it production activity, or space heating to provide comfort in cold weather. Consumption patterns cannot be analysed without reference to these driving factors, and therefore if setting up an energy monitoring scheme, it will be necessary to record them as frequently as the meter readings.

Consumption	Unit	Data available	Which ECA
A1 Popcorn	Cartons	Packing Dept	Packing
A2 Biscuits	Tonnes	Bakery	Bakery
A3 Toffee	Tonnes	Work study	Confectionery

4.3 SCHEDULE OF IDENTIFIED OPPORTUNITIES

The table on page 40 tcan be used to register the potential energy-saving projects for which funding might be sought. For example, one measure identified might be compressed air leakage. If this had an implementation cost of P50,000 and expected annual cash savings of P2,944,535 (through reduced electricity consumption), it would offer a simple payback that is less than 1 month (immediate).

No	Opportunity	Cost (P)	Saving (P)	Elect. Saving kWh	%	Payback Years	CO_2 (tonnes)
2	Compressed air leakage	50,000	2,944,535	645,731	100	Immediate	65.8
3	Add insulation to BA ovens	100,000	262,656	56,600	100	0.5	5.7

Medium/High Cost Saving Opportunities

4	M&T System	445,000	616,267	135,146	100	0.6	13.7
5	Vent system improvement	1,751,000	875,520	192,000	100	2.0	19.6
6	Commission CWCP VSD	100,000	1,020,528	223,800	100	0.4	22.7
7	Compressed air intake improvement	450,000	294,453	64,573	100	1.5	30
8	AHU VSD and Air Leakage Imp.	500,000	1,413,377	309,951	100	0.3	31.5
9	Comp. Air local isolators	300,000	588,907	129,146	100	0.5	13.1
	Total	**4,196,000**	**17,831,361**	**3,909,385**		**0.6**	**421.6**

5 REFERENCES

5.1 SOURCES OF ASSISTANCE

Gee's Energy Saver
(Gee Publishing, +44 20 7393 7666)
This loose-leaf reference manual provides a wide range of information on energy management topics. Its content is subject to regular amendments, including updates to monthly degree-day data.

Energy Systems Trade Association
(www.esta.org.uk)
As the trade association for suppliers of energy-efficiency equipment and services, ESTA provides a useful first point of call in the search for equipment, materials and expert advice.

Institute of Energy
(www.instenergy.org.uk)
The Institute is the UK's professional association for those active in the energy scene (whether as suppliers, users or academics). As such it can provide energy managers with useful individual contacts. Contact the Institute to get a copy of the Standards for Managing Energy.

Combined Heat and Power Association
(www.chpa.co.uk)
In some circumstances, combined heat and power (CHP) can be an important contributor to energy efficiency. The CHPA exists to promote this technology and can provide a great deal of technical and market information, as well as news on grants and subsidies.

5.2 RECOMMENDED INSTRUMENTS AND TOOLS

For the purposes of energy surveys, it is not usually necessary to have traceable calibrated instruments because approximate measures usually suffice. **Exceptions to this rule are noted below.**

- Digital thermometers with type K thermocouple probes. You will need one instrument operating in the range – 50 to 200^{0}C, ideally with 0.1^{0}C resolution, and another for 0-500^{0}C with 1^0 C precision. For high-temperature applications a robust probe is needed. For lower-temperature work, a 'band' probe designed for surface measurements makes a good general-purpose instrument capable also of measuring air temperatures. Even a bare thermocouple junction can be used. Thermocouples can be left in place and read manually by connecting the instrument when required. Compensating extension cable is necessary if the probe will need to be used at a distance (on the end of a pole), for instance.

- A sling hygrometer enables a spot check to be made on wet and dry bulb air temperatures. Alternatively, use a digital relative humidity probe, especially if moisture contents of product need to be measured.

- Non-contact thermometers can be useful to give approximate temperatures of inaccessible surfaces, or to scan for hot spots. An infra-red camera can be hired if large areas need to be assessed in detail. Results of infra-red thermography must be interpreted with caution.

- Miniature data loggers which record temperature, relative humidity, voltage or pulses may be useful for extended tests. Pulses may be logged from a variety of sources including PIR sensors (logging occupancy levels) or even improvised temporary contacts on valve linkages and other moving equipment.

- A light meter. An inexpensive unit will suffice, capable of working over the 100-2000 lux range. Photographic light meters are not suitable.

- A clip-on power meter is useful for checking on lighting circuits, motor consumption and small power loads.

- A compact camera. An inexpensive 35mm compact model is adequate, but a powerful flash is recommended.

- A video camera can be very useful. An inexpensive PC connectable camera can be used in many instances.

- Pressure/vacuum gauges.

- Combustion analysis kit. This is one instrument which ought to be calibrated against a traceable standard. Although relatively expensive, this is a good long-term investment because it enables poor combustion to be detected through regular checks. Always choose one with carbon monoxide measurement. If using oil or solid fuel, you will also need a smoke pump.

- Anemometer to measure air velocities especially in supply and extract ducts.

- Smoke generator to detect air leaks. Alternatively, improvise with tissue paper tell-tales, or a child's bubble maker.

- Torch

- Stopwatch

- Pocket tape measure

- Crowbar (for access to water meter)

- Meter compartment keys

- Walkie-talkie radio or mobile telephones to co-ordinate 'drop tests' when one party is reading meters while another starts and stops equipment.

- Permanent metering should not be overlooked as a source of date. Manually read at frequent intervals, it can provide useful profile information. Do not forget that on equipment with fixed power demands, an elapsed-hours counter will provide a rough estimate of demand.

  Instruments which are too expensive to buy can be hired.